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DEVELOPMENT OF AUTOMATIC MANIPULATORS FOR PLASTIC INJECTION MACHINES

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KEYWORDS

Bowden cables, Automation, Mechanical design, Productivity, Automotive industry

ABSTRACT

The automotive industry is a competitive sector, always asking for improvements in productivity, efficiency and quality. This is the reason why the demand for automation of processes arises, resulting in relying less on manpower.

Bowden cables are mechanical elements that allow the transmission of motion between two or more systems. They are most of the time not visible for the user. Some examples of applications inside the car are opening doors, windows, seat's adjustment, among many others.

At present, the production of Bowden cables is done by multiple working stations with multiple operators. This work is focused on the workstation where the end of the conduit is injected. At the moment, there are injection machines with a capacity of 8 conduits at the same time and one operator at every injection machine. These injection machines need a lot of space, spend a lot of energy and usually present persistent breakdown problems, needing maintenance.

The future outlook of the company is, to have smaller injection machines with a capacity of 4 conduits at a time and one operator for 2 injection machines. These injection machines are easier in maintenance and also occupy less space, consuming less energy as well. The main goal for this project is to make it possible to have 1 operator at 2 injection machines. The possibility to fully automate was rejected as it is really hard to automate the feeding of the conduits in the injection machines due to low stiffness of the conduits, becoming hard to align them in the mould.

The proposed solution to make this happens is to design a manipulator to take out the 4 conduits and the scrap out of the mould. The scrap and the conduits then need to be separated, scrap to a recycling box and the conduits to a production/supply chain box.

The manipulator has been successfully designed, after a thorough comparison of a variety of possibilities. All the components that were needed for this concept have successfully been defined, calculated, selected and integrated into the design. After the designing process, a budget and payback calculation has been done, as well as a return of investment. Lastly, a maintenance manual and an assembly manual has been elaborated in order to ease the assembly of all the components.

The results after implementing the designed solutions are a reduction in energy consumption of the injection peocess (79,8%) and an improvement in productivity (12,0%).

PALAVRAS CHAVE

Cabos de comando, Automação, Projeto mecânico, Produtividade, Indústria automóvel

RESUMO

A indústria automóvel é um setor competitivo, mas sempre ávido por melhorias de produtividade, eficiência e qualidade. É por esse motivo que surge a procura pela automação de processos, resultando na necessidade de menos recursos humanos.

Os cabos de comando são elementos mecânicos que permitem a transmissão de movimento entre dois ou mais sistemas. Na maioria das vezes, eles não são visíveis para o utilizador. Alguns exemplos de aplicações dentro do carro são abrir portas, janelas, ajuste de assentos, entre muitos outros.

Atualmente, a produção de cabos de comando é feita em várias estações de trabalho através de vários operadores. Este trabalho está focado na estação de trabalho onde a espiral é sujeita à injeção de terminais. Atualmente, existem máquinas de injeção com capacidade para 8 espirais ao mesmo tempo e um operador em cada máquina de injeção. Essas máquinas de injeção ocupam muito espaço e apresentam problemas constantes de manutenção.

A perspectiva futura da empresa é ter máquinas de injeção com menor volume e capacidade para injetar em 4 espirais de cada vez e necessitando apenas de um operador para cada duas máquinas de injeção. Essas máquinas de injeção são mais fáceis de gerir em termos de manutenção e também ocupam menos espaço. O principal objetivo deste projeto é tornar possível um operador em duas máquinas de injeção. A possibilidade de automatizar completamente o processo foi rejeitada, pois é realmente difícil automatizar a alimentação das espirais nas máquinas de injeção. A razão por detrás disso é o alinhamento de alguns tipos de espiral.

A solução proposta para fazer isso acontecer é projetar um manipulador para retirar as 4 espirais e os canais de alimentação/gitos do molde. A sucata e as espirais precisam ser separadas, sendo a sucata encaminhada para uma caixa para reciclagem e as espirais para uma caixa de produção/logística interna.

Os resultados após a implementação das soluções projetadas são uma redução no consumo de energia do processo de injeção (79,8%) e uma melhoria na produtividade (12,0%).

LIST OF SYMBOLS AND ABBREVIATIONS

List of abbreviations

AC	Alternating current
ACEA	European Automobile Manufacturers' Association
AFIA	*Associação de Fabricantes para a Indústria Automóvel*
BS	British Standard
DC	Direct current
DIN	Deutches Institut fur Normung
E	Energy
EN	European Norm
et al.	*et alia* (and others)
Etc.	*Et cetera* (and so on)
EU	European Union
FEM	Finite Element Method
FICOSA	Ficosa International S.A.
GDP	Gross Domestic Product
I	Current intensity
ISO	International Organization for Standardization
M	Moment
M_R	Moment around point R
NOK	Not okay
OK	*oll korrekt* (all correct)
P	Power
PLC	Programmable logic controller
PNP	Positive, Negative, Positive
PTFE	Polytetrafluorethyleen
R&D	Research and development
ROI	Return on investment
SWOT	Strenght-Weakness-Opportunities-Threats
UK	United Kingdom
USA	United States of America

List of units

A	Ampere
Hz	Hertz
kg	Kilogram
N	Newton
N·m	Newton-metre
V	Volt
W	Watt
kWh	Kilowatt-hour
mm	Milimetre
MPa	Mega Pascal
s	Second
°	Degree
#	amount

List of symbols

€	Euro
φ	Power Factor
σ	Stress
ϵ	Strain
%	Percent

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INTRODUCTION

1 INTRODUCTION

1.1 Contextualization

The automotive industry is still one of the biggest players in the world economy. This can be easily proved if we have a look at the numbers of cars produced worldwide. In 2018 there were more than 95 million cars produced [1]. This is made possible through a lot of innovation, which will allow to overcome the current climate problems also generated by this industry.

This industry is competitive. Therefore, the industry is always looking for ways to automate their processes. The automated processes are more efficient than labour work but the quality still needs to be guaranteed. To make the process as efficient as possible, it also needs to be flexible. There are a lot of different demands by the customer when ordering a car and the assembly line needs to take this flexible manufacturing into account. It needs to be able to adapt fast to the demanded situation to be competitive.

Bowden Cables are mechanical elements that allow the transmission of motion between two or more systems, which can be divided into actuator systems and receiver systems. They can be found in systems for opening doors, windows, seat's adjustments, among many others [2]. These cables come in a lot of varieties which means that the production needs to be flexible. The production is still really labour-intensive. The different parts of the complete Bowden cable are made by operators at different workstations.

1.2 Main goals

Due to the age of the injection machines and troubles brought in terms of maintenance, the company intends to change from Fiser® big injection machines to small injection machines, so-called Babyplast®. These machines have the capacity to inject four conduits per cycle, instead of eight as the Fiser® machines. Thus, the process needs to be improved in terms of machines' layout and operation. Nowadays, each operator is responsible for one machine. In the future, with the Babyplast®, each operator needs to be responsible for two machines. Thus, the process needs to be automated. One operator remains needed because the task to put the conduits into the mould is hard for a manipulator/robot due to low stiffness of the conduits. Thus, at this point, it is not possible for the process to become fully automated. To fulfill the main goal, some sub-goals to complete along the way need to be assigned:

1) Understand the production process of Bowden cables in general;
2) Focus the study in the conduits and its manufacturing process;
3) Get the required cycle times to produce conduits;
4) Study the needed flexibility in producing different conduits;

5) Keep in mind a suitable ROI (Return on investment)

The solution for this problem is to make a manipulator that can take out the conduits and scrap after injection of the end of the conduit. The operator will only need to put the conduits at the machines, aligning them as necessary.

1.3 Welcoming company

Fico Cables produces a variety of mechanical components for vehicles. The company is situated in Rua do Cavaco 115, Vermoim, 4470-263 Maia, Portugal (Figure 1).

Figure 1: Fico cables site in Maia [3].

This work was carried out under the company supervision of Ing. Mário Cardoso and started in February of 2020, having ended in July of 2020.

1.4 Methodology

The methodology used to reach the goals was as follows:

1) Understand the problem and current process of the Bowden cables production processes and especially the process of the end of conduits' injection;
2) Define the scope of the project in consultation with the supervisors;
3) Collecting the necessary information and already existing drawings;
4) Get ideas of the already existing manipulators inside the company;
5) Define the requirements of the product holder for the first injection;
6) Define the requirements of the product holder for the second injection;
7) Brainstorm and compare different possible solutions;
8) Design the product holders for first and second injection;
9) Get feedback from the stakeholders;
10) Define the requirements of the manipulator and gripping system;
11) Brainstorm and compare different possible solutions;
12) Design the manipulator with the appropriate gripping system;
13) Get feedback from the stakeholders;
14) Calculate the necessary pneumatic equipment, supporting frames and standards components;
15) Finalize the designs of the most suitable solution;
16) Produce the 2D drawings in order to fabricate the components;
17) Measure and record power consumption of both types of injection machines in service;
18) Define the total cost of the most suitable concept;
19) Determine the ROI;
20) Produce an instructions manual to assemble the whole system;
21) Writing of the thesis.

1.5 Framework

The structure of the thesis is essentially built out of four parts:

1. Introduction
   This part is where the reader is put into contact with the theme of the thesis, the objectives that were lined out and the methodology used to overcome the challenges is decribed.
2. Literature review
   The literature review intends to put the reader aware about the theme related to the thesis, reviewing technical and scientific developments that have been published in books or journals related to the subject.
3. Development of the practical work
   The development of the work is presented here with a critical analysis of the obtained results.

4. Conclustions
   The conclusion about the work are drawn out here and the main contributions brought by this work are highlighted.

THEORETICAL CONTEXTUALIZATION

2 THEORETICAL CONTEXTUALIZATION

2.1 Automotive industry

There is still an amazing car culture across the globe. Everyone is relating a car to freedom. It allows to go wherever anybody want whenever anybody want. The trillion-dollar automotive industry is making the most out of this culture. The industry is involved in every aspect of the car. This includes design, manufacturing, maintenance and sales. Some of the biggest players in the automotive industry are Volkswagen (Germany), Toyota (Japan), Nissan (Japan), General Motors (USA), Ford Motors (USA) and Fiat (Italy) [4].

There are a lot of different methods used by the main manufacturers in the production of cars. But, some basics are still the same. One really good example is the implementation of Fordism. Henry Ford was the first to implement a fast-moving assembly line with standardized products. This was also made possible through the combination of robots and manual labor [5].

2.1.1 Automotive industry in the worldwide economy

In 2018, there were more than 98.1 million motor vehicles produced worldwide. It is possible to see the contribution in percentages covered by different regions around the world in Figure 2.

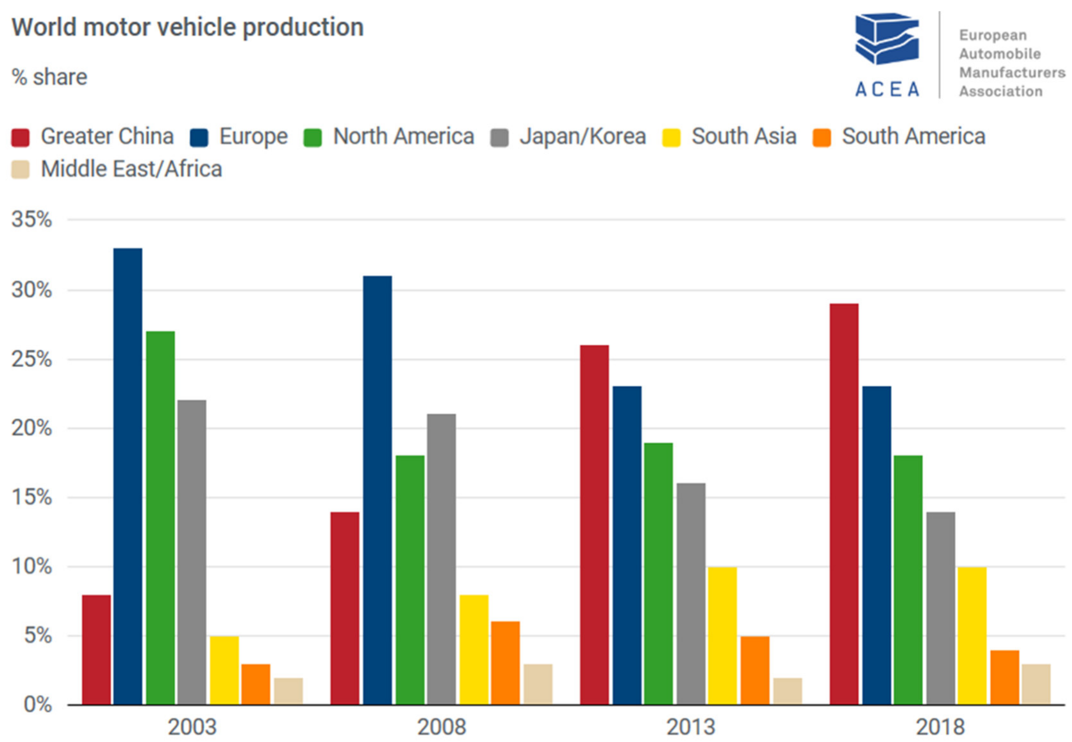


Figure 2: Percentage of motor vehicle production by world region in function of the of total produced cars [6].

It is possible to see that there is a shift of the biggest vehicles' manufacturerers from Europe to Greater China in recent years. The production of Greater China was around 28 million units compared to Europe, which has produced around 18 million units. From 2017 to 2018, it is possible to see in Figure 3 a decrease of 4% and 0,2% for Greater China and Europe, respectively.

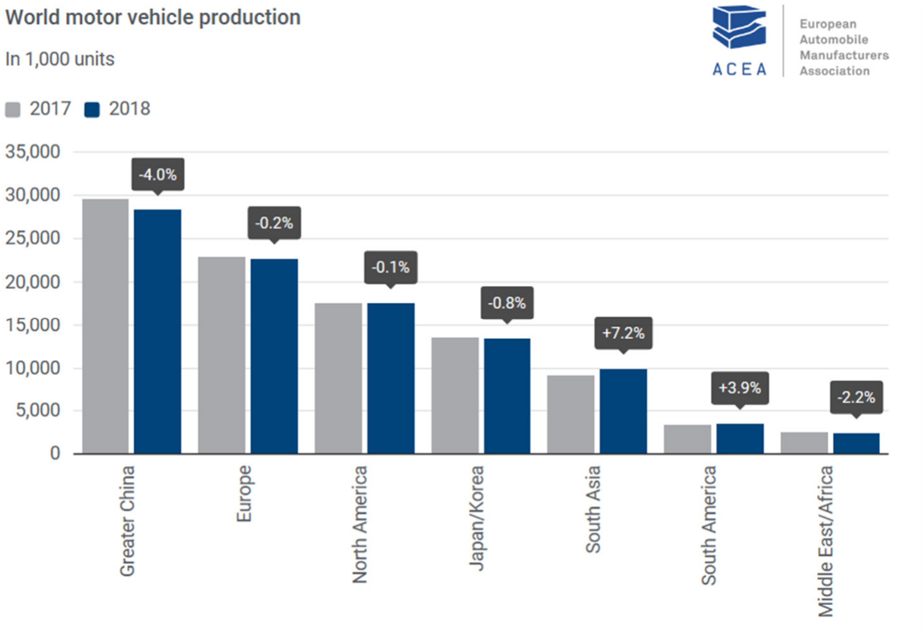


Figure 3: Motor vehicle production in function of units produced by different regions [6].

The above information is based on two kinds of vehicles, commercial and passenger vehicles. It is possible to see the million units produced and the change compared to the last year for both in Figure 4 and Figure 5.

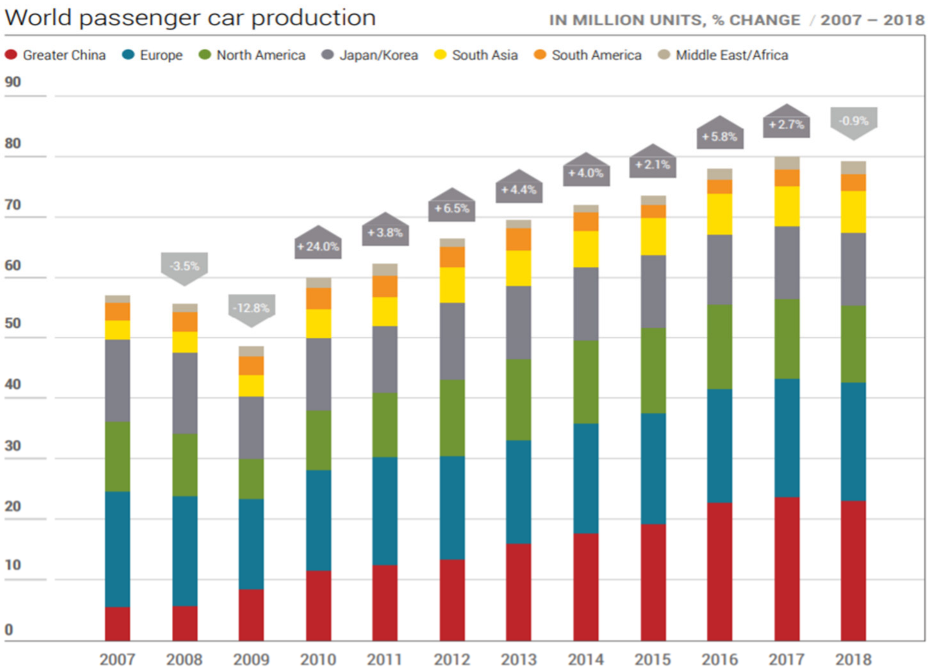


Figure 4: World passenger car production [7].

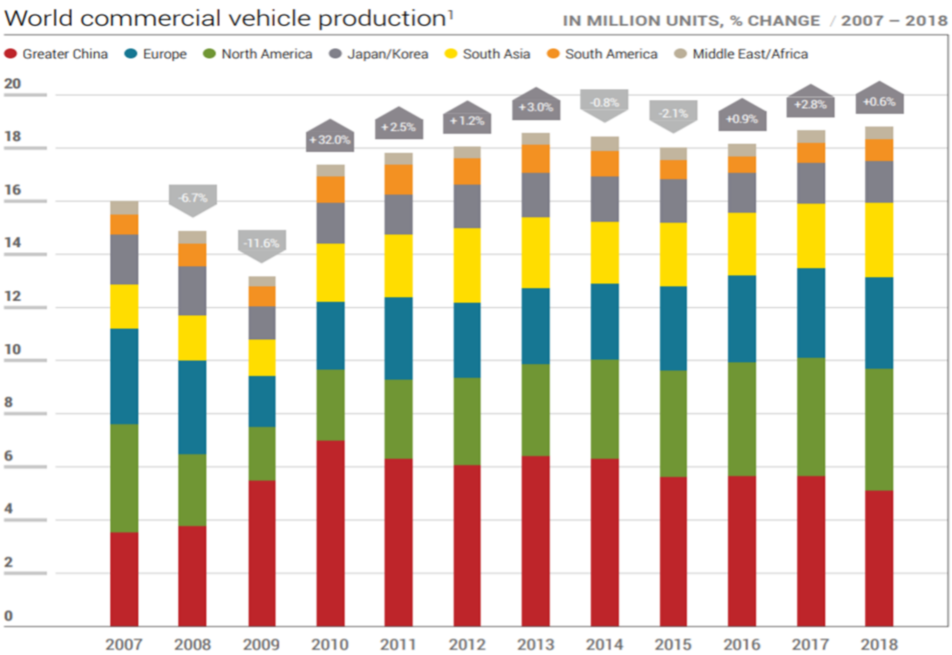


Figure 5: World commercial vehicle production [7].

After looking at the numbers, it is obvious that the world passenger car production is a lot bigger than world commercial vehicle production. There are around 79 million passenger cars produced compared to 18.5 million commercial vehicles.

The automotive sector is a big employer in the EU. From Figure 6, it is possible to conclude that in 2017 the automotive sector was responsible for around 13.8 million jobs. This total includes direct manufacturing, indirect manufacturing, use of automobiles, transport and construction. This accounts for 6.1% of all EU jobs [7].

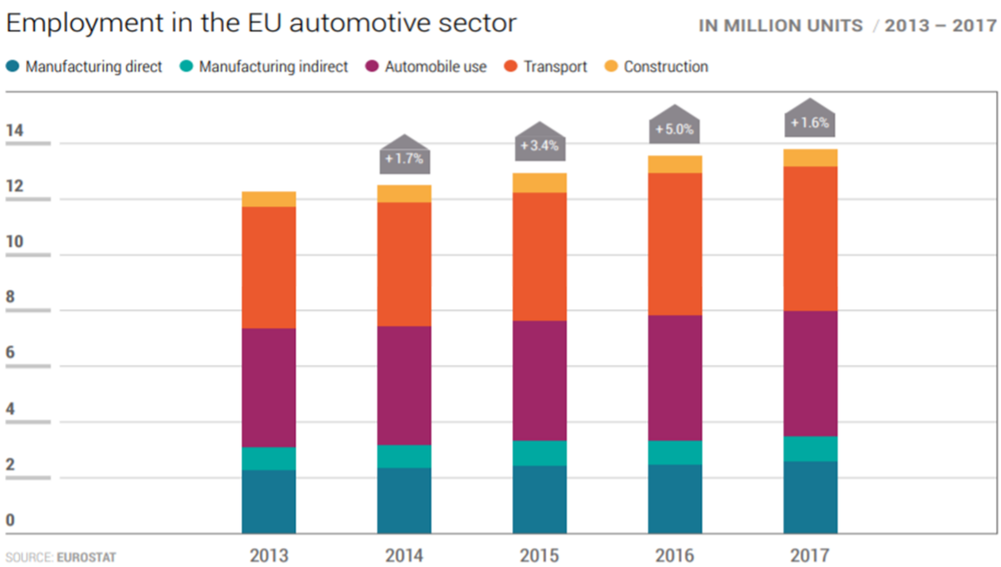


Figure 6: Employment in the EU automotive sector [7].

The whole sector is driven by people wanting to travel by car. Looking at some stats (Figure 7), the number of people driving a car in the EU is 602 per 1000 inhabitants in 2017.

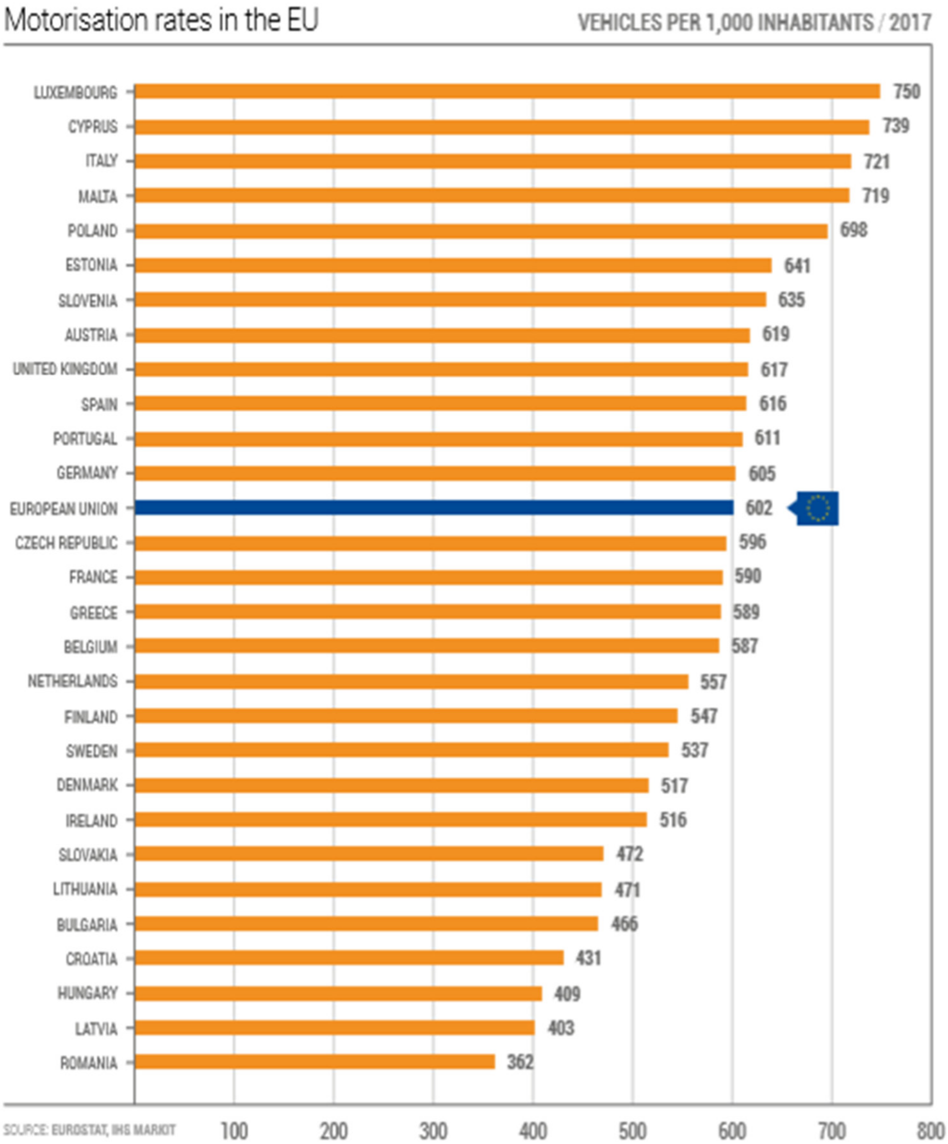


Figure 7: Motorisation rates in the EU [7].

The auto industry is a key sector of the economy for every major country around the world. It does not only offer direct employment in the production of cars. The automotive industry has a lot of suppliers concerning car manufacturing. A few of the biggest sub-sets or components suppliers in the automotive sector are Robert Bosch Gmbh, Denso Corp., Magna International Inc., Continental AG, etc. Thus, it is safe to say that the car manufacturing industry takes a lot of direct and indirect employment for its account. Each direct job creates five indirect jobs. Thus, in total, this makes that more than 50 million people, in the investigated 39 countries, have a job because of the auto industry. In Figure 7, it is possible to see the relation of different sectors to the automotive industry.

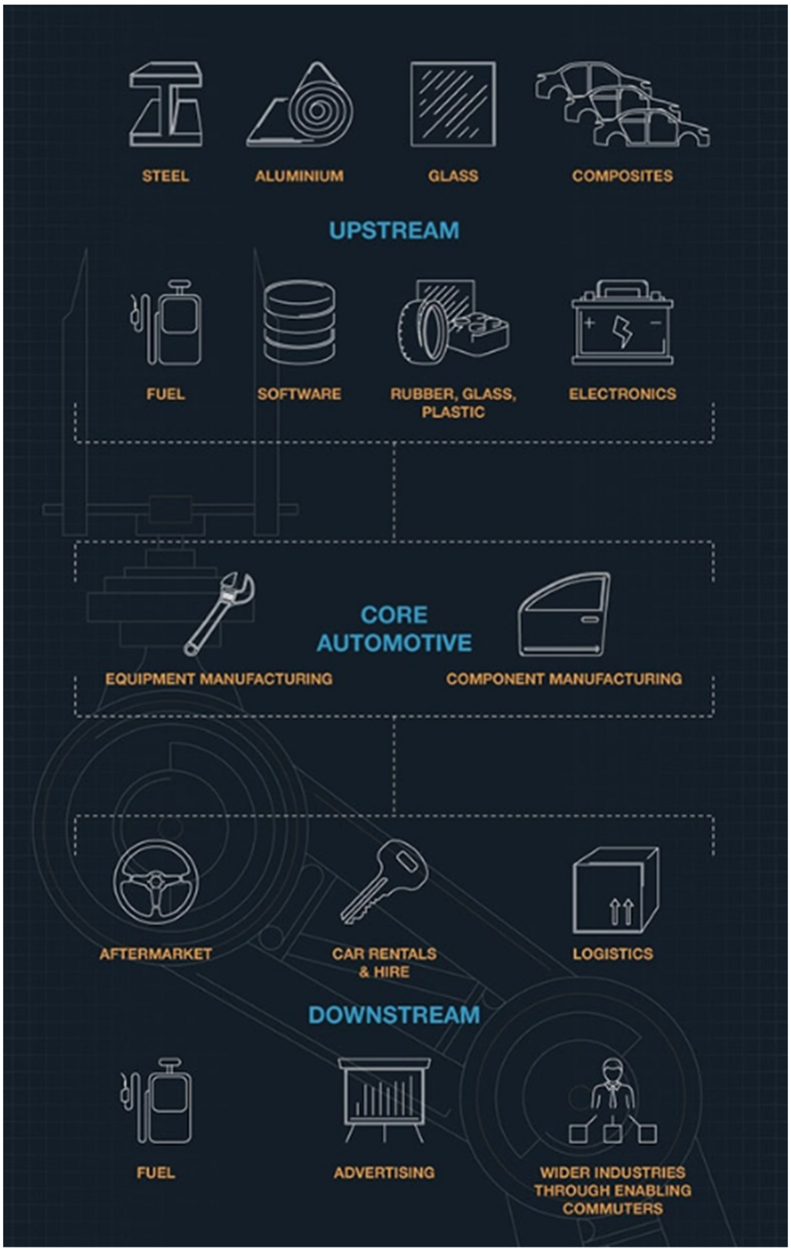


Figure 8: Sector involvements in the automotive industry [8].

2.1.2 Automotive industry in the Portuguese economy

The automotive industry is a core sector of the Portuguese economy. The industry represents 4% of total GDP and it is represented by 29 000 companies, being responsible for 124 000 direct jobs, a business volume of 23,7 thousand million euros and 21,6% of the total fiscal revenues in Portugal. It represents 11% of total Portuguese exportations. This is all made possible by the Portuguese technical skills gained in this field and the logistic infrastructures they have available. As can be seen in Figure 9, there are four major car-manufacturers in Portugal: Toyota/Salvador Caetano, PSA Peugeot/Citroën, Mitsubishi FUSO Trucks and Volkswagen AutoEuropa [9]. An illustrative representation of the automotive industry in Portugal can be seen in Figure 9.

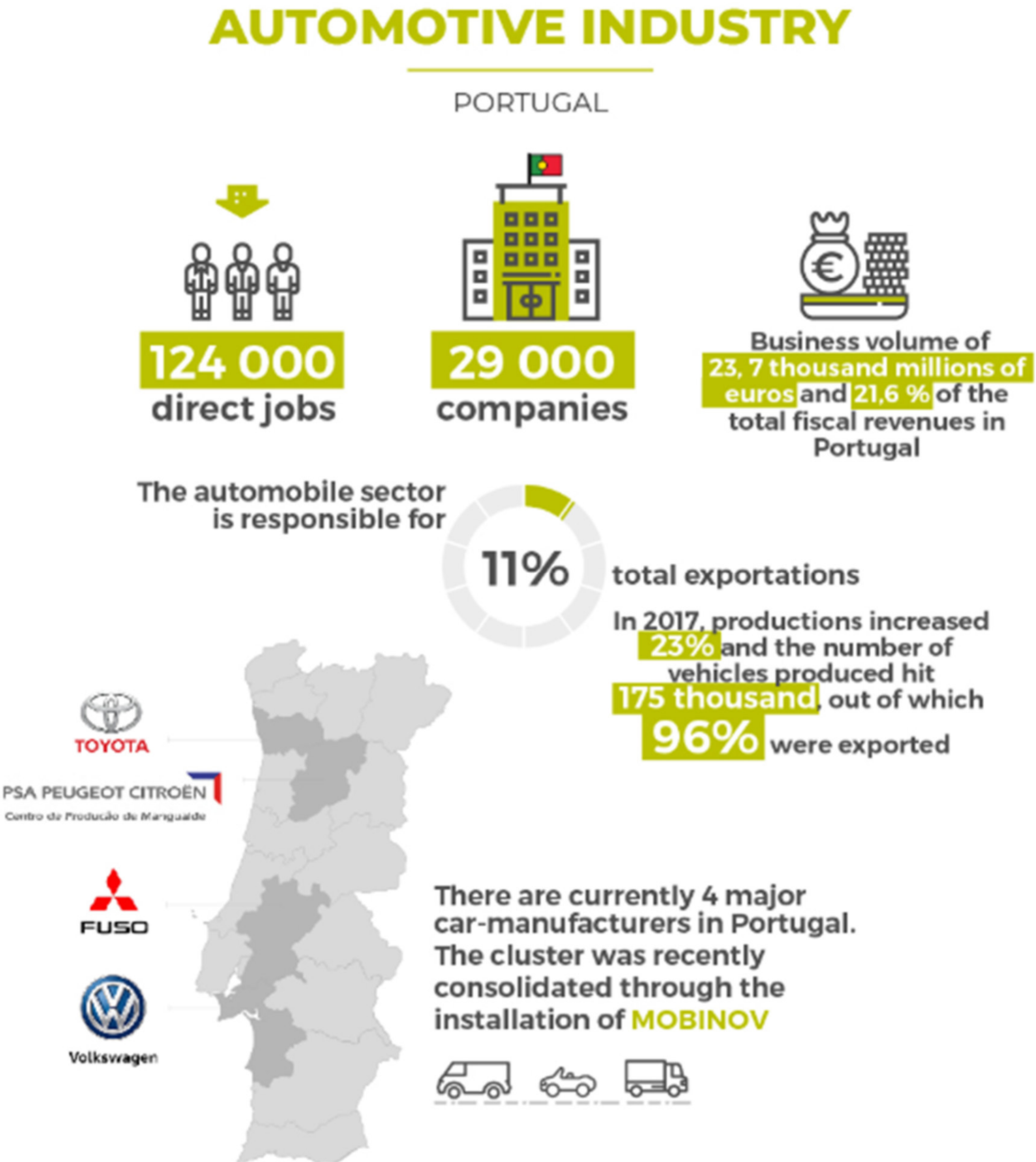


Figure 9: Automotive industry in Portugal [9].

2.1.3 Automotive components industry in Portugal

Portugal produces over 10 000 distinct car parts which are exported and put together on the assembly lines of international automakers such as VW, BMW, Jaguar, Land Rover, Aston Martin, Porsche, Seat, Fiat, Ford, Renault, and Nissan, among others. More than 230 manufacturers exported 9,7 billion euro worth of car parts only in 2019, representing 16% of exports of tradable goods. Most components in 2019 were exported to Spain followed by Germany. The export by region/country is visualized in percentage in Figure 10.

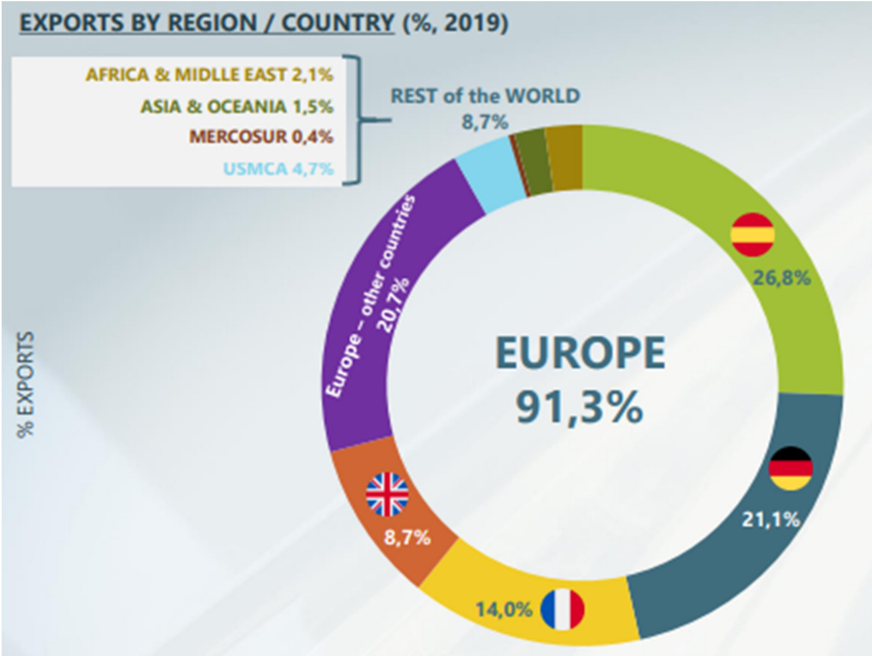


Figure 10: Exports by region/country of the component industry [10].

The industry had a turnover worth 12 billion euro, representing 6% of Portugal's GDP. The turnover and export of the industry raised 4% and 3% compared to last year's numbers. The trend over the last nine years can be seen in Figure 11.

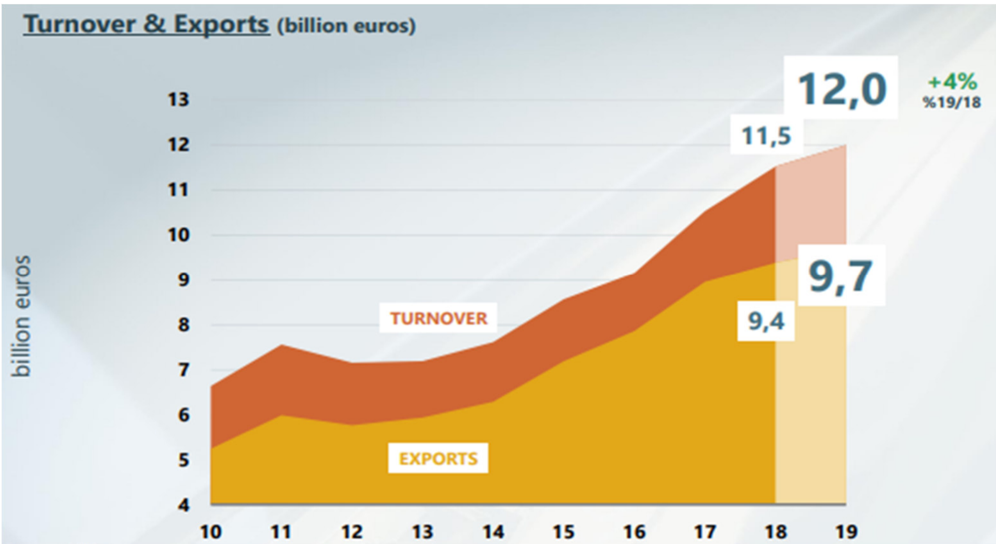


Figure 11: Turnover and export of the components industry [10].

The exported car parts have a lot of varieties [11]:

- low-tech;
    - plastic parts;
    - rubber parts;
    - composite parts.
- engine parts;
- gearboxes;

- high-tech electronics;
- moulds.

The activity with the biggest impact on the turnover is metalurgy (33%), followed by electric/electronics (29%) and plastics, rubber and other composites (18%), to fulfill the top 3 (Figure 12).

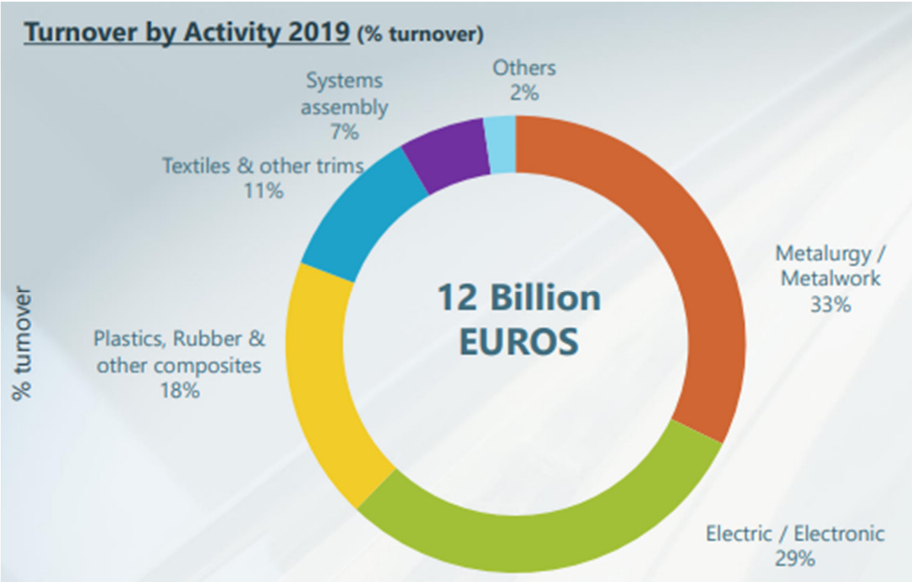


Figure 12: Turnover by activity in 2019 (%turnover) [10].

These industries are spread over Portugal. The three cities with the most manufacturing sites are Aveiro (60), Porto (48), and Braga (36). A map of Portugal with the different locations of manufacturing sites can be seen in Figure 13 [10].

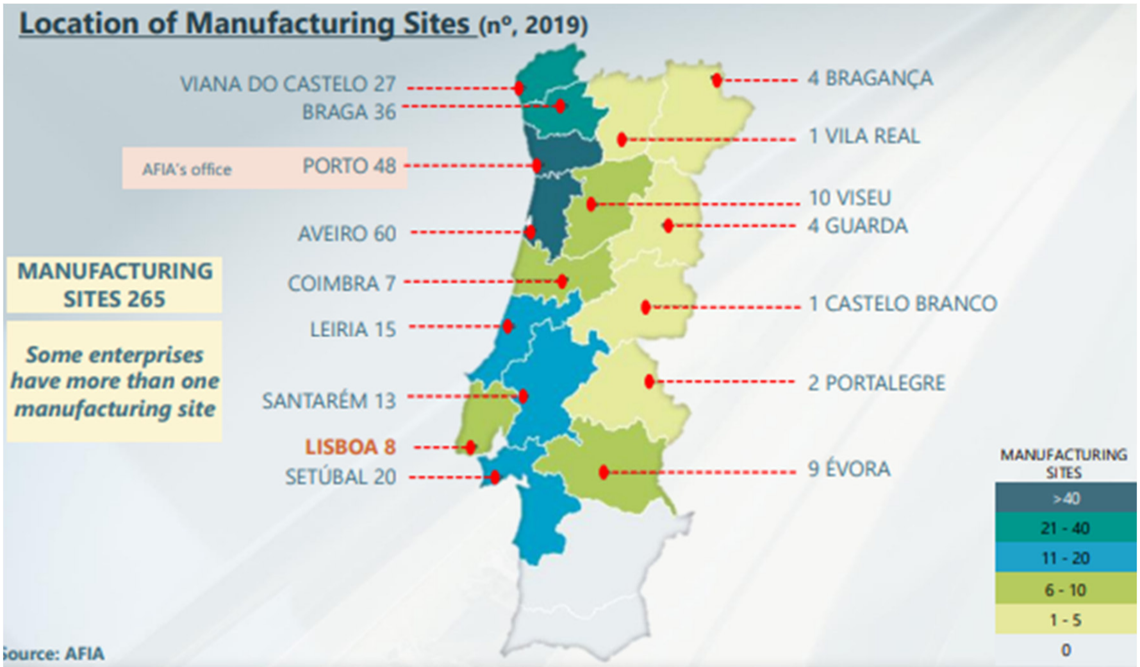


Figure 13: Location of manufacturing sites [10].

2.2 Bowden cables

2.2.1 Bowden cables and its constitution

The origin and invention of the Bowden cable is under discussion. On one side, the invention has been designated to the founder and owner of the Raleigh Bicycle Company, Sir Frank Bowden, who started replacing the rigid rods with flexible wound cables used for brakes. There is no evidence proving this. On the other side, there is evidence of a patent of the Bowden mechanism granted in 1896. It was invented by Irishman Ernest Monnington Bowden. The main element of this was a flexible tube (made from hard wound wire and fixed at each end) containing a fine wire which could transmit pulling, pushing or turning movements on the wire rope from one end to the other. It is reported that "on 12th January 1900, E. M. Bowden granted a licence to The Raleigh Cycle Company of Nottingham", whose directors were Frank Bowden and Edward Harlow. At this signing, they became members of 'E. M. Bowden's Patent Syndicate Limited'. The syndicate included, among others, R. H. Lea & Graham I. Francis of Lea & Francis Ltd, and William Riley of the Riley Cycle Company. Undoubtedly, this is why E. Bowden and F. Bowden are sometimes confused today [12].

An unpublished typescript exists in the archives of the National Motor Museum, written by the son of one of Bowden's employees that attempts to claim the invention of the cable for his father to the point of suggesting that it was never applied to bicycles before 1902. Although this is easily disproved by reference to 'Cycling' or the other UK cycle press through 1896–97, it serves to remind one of the attempts made to rewrite cycle history through priority claims. British National Archives describes in its narrative, a flexible cable brake for cycles was separately 'invented' by George Frederick Larkin, a skilled automobile and motorcycle engineer, who patented his design in 1902. He was subsequently recruited by and worked for E.M. Bowden until 1917 as General Works Manager [12].

The Bowden cable was designed to take the place of the complex cable and pulley mechanisms for bicycles and automobiles. As of today, their use is spread in all kinds of industries. Where different applications in the car are described in the next paragraph.

2.2.2 Bowden cables and its use in car vehicles

Bowden cables are used in many different applications in today's vehicles. They are not noticed by the user most of the time. It is a type of flexible cable used to transmit a mechanical movement or (pulling) force by the flexible moveable combination of an inner cable relatively to a hollow outer cable housing. The housing, usually called a conduit, is generally of composite construction, consisting of a helical steel wire, often lined with plastic, and with a plastic outer sheath. The inner cable is most commonly made of steel or stainless steel. The behavior of Bowden cables is dependent on the effective direction. In today's cars, as well as future ones, there are a lot of mechanisms using Bowden cables. Most of them are invisible to the user. An enumeration of some common applications of Bowden cables inside vehicles can be seen ahead [13]:

- release of the bonnet;
- trunk and fuel opening;
- hood opening;
- release of the door locks by inner and outer door handle;
- shift cable to the transmission;
- folding down the front seats' backrests in two-door vehicles;
- window lift inside the doors;
- remote release of the rear seats' backrests.

In Figure 14, accompanied by the description in Table 1 and Figure 15, it is possible to see a few types of Bowden cables and where they are placed inside the vehicle.

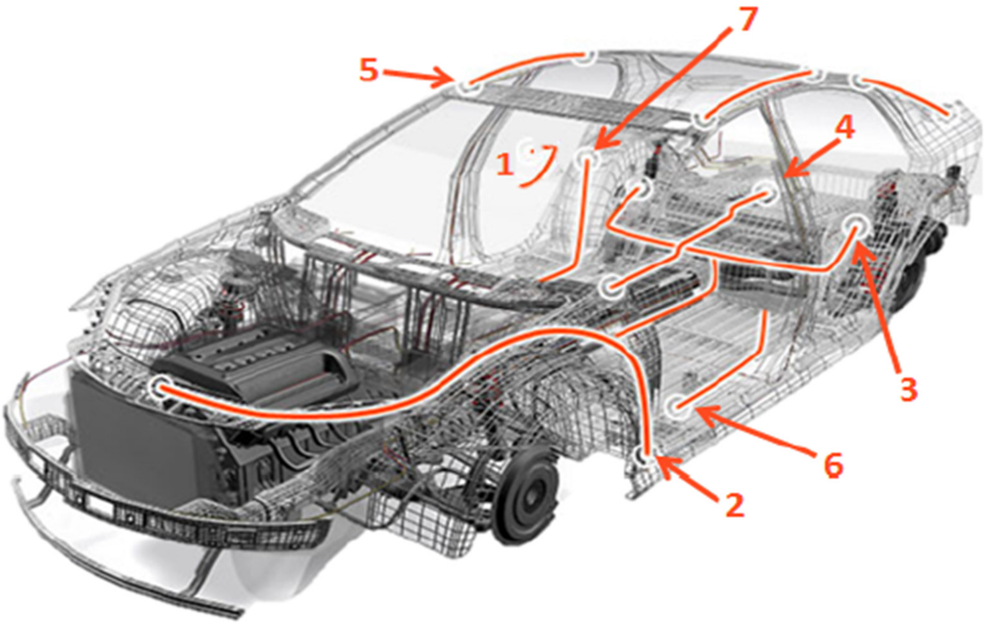


Figure 14: Places where Bowden cables are used inside a vehicle.

Table 1: Legend for the numbers used in Figure 14.

Number	Legend
1	Automatic window cable
2	Hood opening
3	Brake valve
4	Trunk opening
5	Roof glass cable
6	Seat adjustment cable
7	Door opening cable

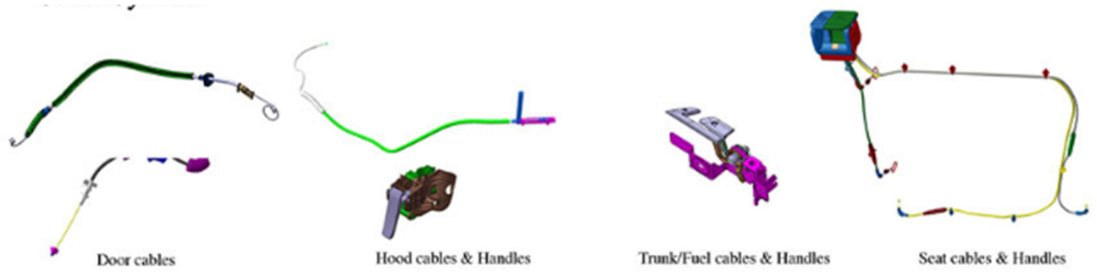


Figure 15: Different types of application of the Bowden cable [14].

The Bowden cable is built-up out of several components that will have a different function in the correct functioning of the cable. The most influential parts are:

Zamak end of the cable

The connection is always carried out through the end of the cable (terminal). These terminals can have different formats (Figure 16) and are carried out through different production processes:

- Punching;
- Over-Injection;
- Ultrasound welding.

The production process of injection is only applied to Zamak terminals (Figure 17). Other processes are used for terminals in steel, brass or sintered steel. To increase the resistance against corrosion, steel terminals are often protect through zinc or phosphating operations. Terminals that are obtained by turning (Figure 16a), stamping (Figure 16b) or forging (Figure 16c) are usually attached to the respective cables through the pressing process. However, in the case of turned and stamped terminals, a heating treatment is generally applied. This is causing stress relief that will prevent them from breaking during pressing.

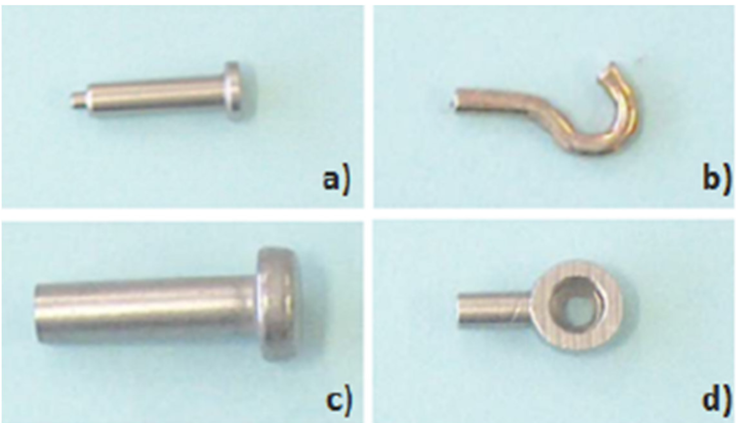


Figure 16: Different endings a) Turned; b) Stamped; c) Forged; d) Sintered [15]

The greatest advantage of these Zamak injected terminals, seen in Figure 17, is being directly injected on the cable avoiding the stamping operations. Zamak, an alloy of zinc and aluminium, has good corrosion resistance. Both, zinc as it has a protective effect and aluminium by creating an oxide layer on the surface, prevent the corrosion's spread. The combination of the material and the injection process increased the productivity and the possibility of creating new geometries. In Table 2 the advantages and disadvantages of the Zamak terminals compared to the steel terminals are described.

Table 2: Advantages and disadvantages for the terminal injection of Zamak compared to steel terminals.

Advantages	**Disadvantages**
• A faster and simpler process • More flexibility in geometries • Better corrosion resistance • No need for pressing resulting in no variations in geometry • Low dispersion in tensile strength • Stable dimension • Low cost of raw materials • Implementations in semi-automatic and automatic systems are easier	• Injection machines are more expensive • Higher energy cost to bear with injection machines • Need to make a flower

Figure 17: Zamak injected terminals [15].

Steel cable

The steel cables (Figure 18) are an important part of the Bowden cable. Without the surrounding parts, the cable would not be of much use. A rope, wire or cable, is a uniform helical construction of wire filaments together. They are used in a variety of operating conditions. Rope constructions contain larger filaments with greater resistance to abrasion. However, they are less flexible. In turn, cable constructions will have more wire filaments, with more flexibility while being less resistant against abrasion. The strand consists of two or more connected wire filaments and is normally constructed 1 x X, with X being the number of filaments surrounding the core (for example 1 x 7, 1 x 19). The wire rope has three or more strands together, and its construction is usually designated as the number of core wires, times the number of strands that surround the core (for example 7 x 7).

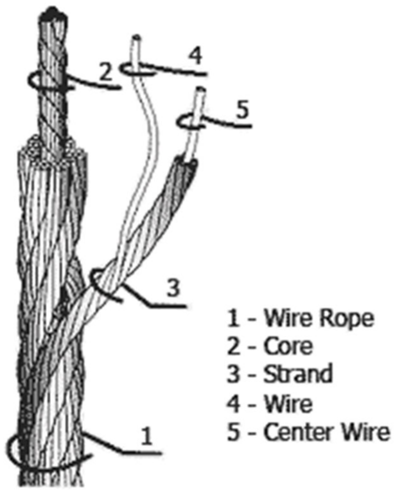


Figure 18: Construction of the steel cable [16].

The final diameter of this type of cable depends on the functionality and the load is intended to carry. In a small comparison, a cable for the application of opening/closing doors will have a smaller diameter than the ones used for breaks. The Zamak terminals at the end of the cable are made by injection, as previously mentioned, and a flower needs to be provided at the ends of the cable. This flower (Figure 19) increases the contact surface between the terminal and the cable, allowing a better adherence of the cable and improving the terminal tensile strength.

Figure 19: Different type of cables with a flower [15].

These flowers need to be correctly formed, if not this leads to a defective assembly of the Zamak terminal together with the cable. In Figure 20 it is possible to see some examples of defective flowers.

Figure 20: Cables wit a defective flower [15].

The remaining components that are integrated into the Bowden cable are depending on the function the cable has. A few of the other frequently used components are :

- Internal tube (Figure 21):
  The internal tube prevents friction of the metal cable with the spiral and also reduces the noise.
- Spiral/conduit (Figure 22):
  The spiral prevents contact of the steel cable with other components to avoid noise. It guides the steel cable and protects it by being laminated, armed or braided. It is also used as a fixing point for the steel cable.
- End of the spiral/conduit (Figure 23):
  They are used to attach the cable to the required mechanism.
- Grommet (Figure 24):
  It is protecting the cable for fluid leaking in. It is some kind of part dividing wet and dry.
- External tube (Figure 25):
  The external tube is placed to avoid noise. Three different kinds of external tubes are mainly used:
    - Star tube: To reduce noise caused by impact:
    - Rubber tube: When the cable passed a dry to wet zone or the other way around;
    - Sponge tube: To reduce noise caused by friction.

Figure 21: Internal tube [15]

Figure 22: Spiral [15]

Figure 23: End of the spiral [15]

Figure 24: Grommet [15]

Figure 25: External tube [15]

2.2.3 Processes involved in Bowden cables production

The industry is constantly trying to improve the production process. Due to global competition, the automotive component industry has carried out a large number of studies to stay competitive and profitable. Today, there are still a lot of different workstations used for the production of Bowden Cables. Studies have been carried out to improve the production of the Bowden cables (Table 3).

Table 3: Improvements in the production of Bowden cables.

Reference	Description
[17]	Moreira *et al.*, developed a single cell where different manufacturing and assembling processes where integrated. This system was also created flexible enough, to produce more than one product reference. This resulted in a reduction of the overall system life cycle cost as well as the machine start-up time and improve the quality and consistency of the product.
[2]	Martins *et al.* developed a new concept of equipment for the manufacture of Bowden cables for cars. Starting from the current way of producing, implementing improvements such as new operations and increasing the level of automation. By creating a jig and a transport system, the product is transported between all the necessary workstations. By integrating the processes, a dramatic reduction in cycle time and an increase in productivity was achieved. Making the process fully-automated, less dependence on the variability of manpower increased also the quality of the product.
[18]	Ribeiro *et al.* designed a novel system for the introduction of lubricant in control cables for the automotive industry. This design accomplished a tremendous reduction of grease waste. Besides the improvement of the environmental impact, a more competitive and flexible process is achieved.
[19]	Santos *et al.* designed a novel concept of a conduit transport system. The transport system transports the conduit along an automatic production line where different operations are performed on the control cable spiral. The automation resulted in higher reliability, a drastic drop of stoppages due to transport problems of the conduits and a dramatic reduction in set-up time.

Reference	Description
[20]	Rosa *et al.* presented a case study to optimize the production process of an assembly line dedicated to the manufacture of control cables for the automotive industry by using Lean tools and methodologies. This study resulted in a significant increase in productivity and a reduction in assembly line usage. Creating the opportunity for the production of new product references at the assembly line in question.

Today, all the different work stations used in the production of the Bowden cables are seen in Figure 26.

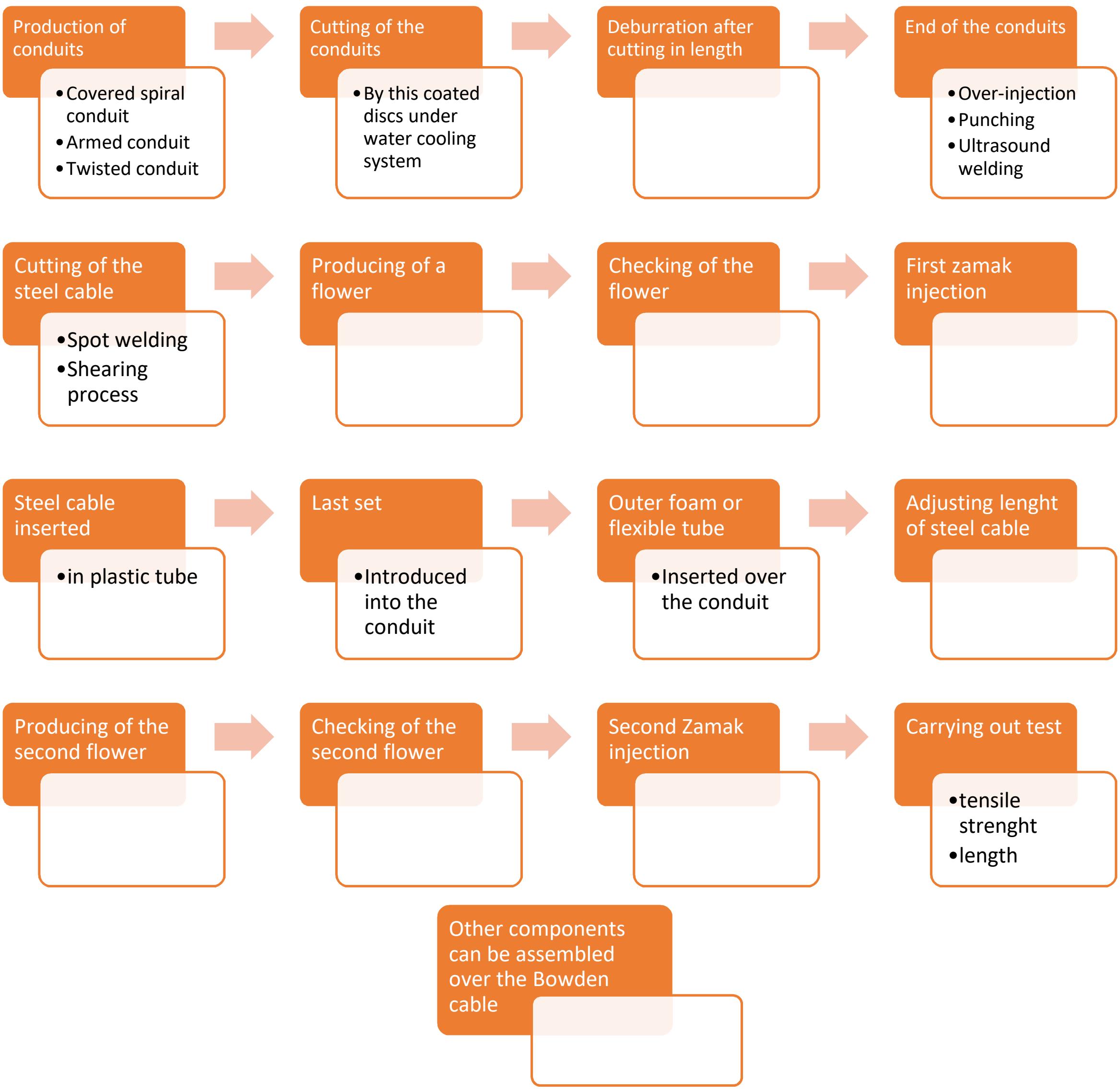


Figure 26: Production process of the Bowden cable.

2.3 Automatizing the manufacturing processes of Bowden cables

2.3.1 Industry needs for automation

A number of factors that are making the industry to increase their automation are described in Table 4 [21] [22].

Table 4: Reasons to increase automation in production processes.

Reason	Description
Increase productivity	Increasing the output/time unit compared to a non-automated system.
Reduction in production cost	By using machines, it is possible to reduce the production cost due to less use of manual production.
Optimization	Detection of the causes of problems, isolating them and eliminating them. This results in good control over the process making it possible to detect critical elements with good repeatability. This way, it is possible to act in a logical and organized way in order to optimize the process.
Reduction or elimination of repetitive tasks	Repetitive and monotonous tasks are causing physical and mental problems for the operators. By implementing automation to perform these types of tasks it is possible to improve the working conditions for the operator.
Improve worker safety	Some tasks can be really dangerous. By automating these tasks it is possible to increase the safety of the operator. The operator will only have supervisory tasks.
Improve product quality	Automation results in a more consistent production of parts with a greater repeatability and conformity. This way a reduction in defect rates will be achieved.
Reduction in delivery times	Automation can drastically reduce cycle times which results in a shorter time between the customer's order until its delivery.
Production of complex parts	Some parts are so small or need to be produced with a certain precision that manual production is out of the question. By using automation, it is possible to produce these kinds of parts.
Efficiency	By using automation improvement in efficiency and quality is accomplished. This minimizes the costs and maximizes profits

The need of automation lies in the increasing demands of the market to greater efficiency in production. Automation presents a solution to these demands, playing an important role in today's industry.

2.3.2 Different types of automation

The automatisation of manufacturing systems means that the company wants to produce a product with less human interaction. The automation can be involved in the assembly line, inspection or material handling on the production line. In some cases, it is possible to make a fully automated process. Some examples of fully automated systems:

- Automated warehouses;
- Automated packaging systems;
- etc.

Automated production systems can be classified into three basic types (Figure 27) [21]:

1) Fixed automation;
2) Programmable automation;
3) Flexible automation.

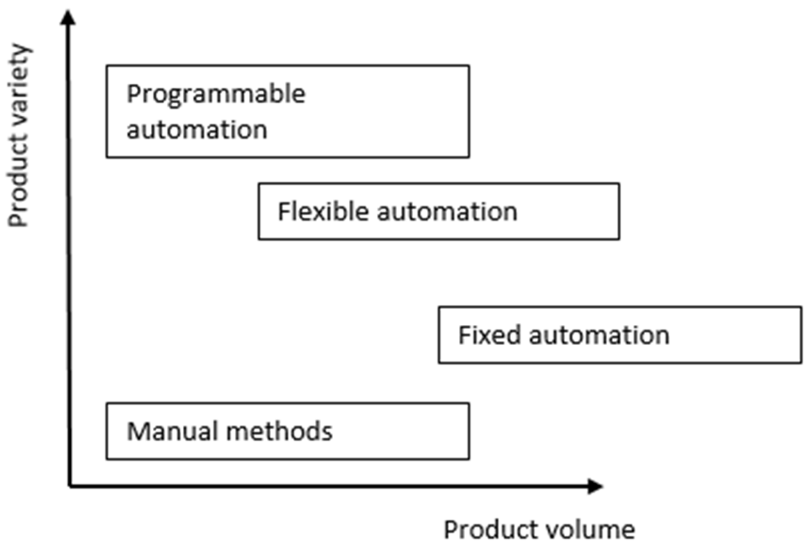


Figure 27: Types of automation in terms of quantity and variety of products [21].

In Figure 27, the use of the three types of automation are outlined according to the diversity of products and the production volume. When a large quantity of products needs to be produced with a small variety of products, fixed automation is most suitable. If there is a large variety of products with a reduced product volume, programmable automation is most suitable. If there is a balance needed between product variety and production volume, flexible automation is most suitable [23].

In the following text, there is more information about the differences between those types [21].

Fixed automation is a system where the sequence of manufacturing/operation is fixed by the equipment configuration. These sequences are usually simple operations like a linear or rotational movement or a combination of them. This type of automation is characterised by :

- High investment for the equipment;
- High production rates;
- Inflexible in case of product changes.

The use of such systems is justified when there are very high production rates, which makes the high initial investment easily recoverable since it reduces the unit cost of products when compared to alternative systems. A good example of this kind of application is automatic assembly machines.

Programmable automation makes it possible to change the sequence of manufacturing/operations to accommodate a variety of products. The sequence is controlled by a program. The program is a set of instructions. A set of different programs with other sequences of operations can be written, helping to manufacture a variety of products. This type of automation is characterised by:

- High investment for the equipment;
    - general equipment;
    - specific equipment.
- Low production rates;
- Flexibility in case of product changes;
- The best system in case of batch production.

Programmable automation is used for low and medium volume production. As mentioned, it is mostly used in batch production. To make a new type of batch, the system can be reprogrammed and, if necessary, the physical set up can be modified to the needs of the new product. As a result of a change in the physical setup, the time to modify the system needs to be taken into account before the new batch can be produced. A good example of programmable automation is industrial robots.

Flexible automation is an extension of programmable automation. It is a system that is capable of producing a variety of products with virtually no time lost for changeovers between products. This includes the time of the physical set up as the time of reprogramming. This means that it is possible to make a variety of products in combination with each other, instead of producing them in separate batches. This type of automation is characterised by:

- High investment for the custom-engineered system;
- Continuous production of a variety of products;
- Medium production rates;
- Flexibility in case of product design variations.

The biggest difference with programmable automaton is, in essence:

- The capacity to change programs with no loss in production time;
- The capacity to change the physical setup with no loss in production time.

They accomplished to have no loss in production time by preparing the programs off-line on a computer. When the program is needed, it is uploaded in the dedicated automated production system. Changing the physical setup between parts is made by making the changeover off-line and then moving it into place simultaneously as the next part comes into position for processing. This canbe implemented, for example, by the use of pallet fixtures that hold the parts and transfer into position at the workplace. The variety of products that can be made using flexible automation is more limited compared to programmable automation.

2.3.3 Automation of industrial machines

The automotive industry has undergone a lot of changes in recent years, going from large series productions with repetitive assembly work supported by fixed automation to flexible production. The next step was, due to the demand for a bigger variety of products, the introduction of flexible automation. Over the years, the industry has been pursuing continuous improvement in production efficiency and saving resources as much as possible (energy, material, human labour). For product manufacturers, the change to go from a manual system to automated systems has always been a challenge. The aim is always to increase productivity, reduce cycle times while meeting the high-quality requirements by the customer and reducing production costs. This way assures the manufacturers remain flexible and competitive due to variation in the market. There are a lot of studies made trying to improve the production of car parts. A number of them can be seen in Table 5.

Table 5: Studies related to automation of processes.

Reference	Description
[24]	Araújo *et al.* worked to eliminate the manual labour in the assembly line of suspension mats. He did a careful study of the workers' movements and, with the results, he has optimaised the production flow. In that flow, he integrated simple automated systems to eliminate manual labour. A new concept for suspension mats transport along the production cell has been created. With this optimization, the assembly line achieved a cycle time of 12 s which is a 40% improvement from the initial assembly line. The optimization also eliminated the risk of mistakes induced by manual labour through the use of automated systems and a decrease in rejected mats.

Reference	Description
[2]	Nuno Martins *et al.* aimed at developing a new concept of equipment for the manufacture of Bowden cables for cars, starting from the concept currently in operation. In this sense, flexible equipment was developed, with several changes and improvements implemented, including new operations and increasing the level of automation of the system. Through the newly developed concept, there is less dependence on manpower factor and associated variability, increasing the quality of the product and operator's work, reducing cycle times (25%) and increasing productivity.
[17]	This work developed by Moreira *et al.* intended to develop and present the real advantages of processes' integration using automation, in opposition to a diversity of inter-dependent automated processes, in terms of work preparation (setups), materials flow and maintainability. A case study is presented, illustrating how the system can be designed, establishing a novel concept of a fully automated equipment, integrating production and assembly systems. Thus, inventories are eliminated and the production management was made easier.
[25]	Figueiredo *et al.* worked to eliminate a previous manual operation (stripping of a coated metallic cable) by adding a device on a current existing machine in order to make it a fully automatic process. He did this by studying the manual cutting process and making prototypes following the trial and error method. With this device implemented on the existing machine, it allows the machine to produce wire ropes up till 2.5 meters long and stripped on both sides with a cycle time of 7 seconds (1000 wire ropes per hour as they are produced in couples). The investment, by using the fully automatic equipment, is paid back in 2.3 years.
[26]	Costa *et al.* made a study on plastic parts of a widescreen washer. An agile concept was developed allowing various types of parts from the same family to be manufactured while also reducing the setup times. The study concluded that automation was the go-to option to improve production and quality while having enough flexibility and agility. Flexibility and agility are leading to better production management concerning the new market requirements: low or medium series with fast delivery and specific requirements from the customer.
[19]	Santos *et al.* designed a novel concept of a conduit transport system. The transport system transports the conduit along an automatic production line where different operations are performed on the control cable spiral. The automation resulted in higher reliability, a drastic drop of stoppages due to transport problems of the conduits and a dramatic reduction in set-up time (97%). Moreover, some mechanical systems were also simplified.

Reference	Description
[27]	Costa *et al.* developed a concept to solve quality problems in the transmission system of automobile wipers namely on an axle. A fully automated equipment capable of receiving, guiding, assembling and controlling the assembly of these axles was developed. The production rate was exceeded by 19%. This results in a more efficient and optimized process due to the ability to perform several tasks at the same time and perfectly synchronized while solving quality problems.
[22]	Magalhães *et al.* developed a new system to collect and reorient newly curved wires by using an automatic machine. The orientation is dependent on the next stage in the manufacturing: over-injection. This implementation causes a big drop in cycle time since the robotic equipment that bends the wire no longer requires a stop cycle simply for another robotic arm to collect the wire, before cutting and positioning it correctly.
[28]	Parreira *et al.* used the A3 methodology to study the improvement of productivity of an assembly line dedicated to the manufacture of brake cables for the automotive industry. This methodology monitors the evolution of key indicators such as productivity per hour and Overall Equipment Effectiveness (OEE) of the assembly line, to define different improvement actions to be executed and achieving the defined target. The implemented solutions increased productivity by 49% and a reduction in cycle times by 33%. The rearrangement and improvement of operations also increased the efficiency of the assembly line balancing in 11%.

Automation is the application of computerized or mechanical techniques to reduce the use of human labour in the process. By using automation we can frequently reduce the cycle times drastically and improve the quality of the product due to less human interaction. Automatic systems can be found in all kinds of applications inside a company such as performing operations in the manufacturing of the product, transportation between workstations, in the assembly of a product, inspection and handling.

2.3.4 Automation of intra-logistics processes

Nowadays, companies have more complex problems due to reducing cycle times and the production of a variety of products. Several tasks are carried out by different automated types of equipment and sub-products need to be conveyed from one workstation to another. Next, is a description of a few methods on how intra-logistics is working nowadays inside manufacturing companies.

In a production company, there are multiple workstations. Between workstations, the sub-products are mostly transported in boxes to the next workstation. The transportation between the different workstations can be executed by different automated equipment such as conveyors, rotating tables, manipulators, etc. The sub-product, that is delivered at the injection machine, is a conduit that is cut on the desired length. These conduits are fed at the cutting machine as a conduit on a roll that came from a different production area. These rolls are transported by a forklift to the desired production area. After, the machine is cutting the conduits on the desired length, which are put by the operator into boxes. These boxes are then moved to the injection machine. The distance between these machines is not far. They are put close together to reduce transport time. These sub-products are then put into the injection machines to create the end of the conduit. The current situation is that the new product is picked out manually and again put into boxes that need to be transported to the next workstation. The next workstation where the conduit is used is to insert the steel cable. At this moment, the steel cable already had some operations themselves (cutting of the steel cable, producing of flower, checking of the flower and a first Zamak injection). It is safe to say that most transportation is performed manually, although some improvements are considered for the future.

There are some new developments. As the industry is always trying to improve cycle times and reducing cost per unit, they try to develop more novel systems that integrate different fully-automated processes and corresponding separate tasks. The raw material can be fed at the beginning of the cell and all the manufacturing and assembling processes are made sequentially in the same cell. The final product is eventually delivered in the final stage of the cell. This makes the material flow easy to control (no intermediate stocks) [17].

Another option to perform the various tasks is to make a novel concept of conduit transportation. The new conduit transport system along the production line implemented innovative mechanical and pneumatic solutions. This way, a reduction of by-products in the process of manufacture is accomplished, extending as well the space for other modules to be coupled to the base equipment in the future [19]. The inefficiency of the process lays greatly in the transport between the different workstations and the intermediate stocks. The production rate of those workstations is also different, which causes unnecessary intermediate stocks.

Figueiredo *et al.* made a new concept for the automotive wire production which solved a lot of these problems, by implementing the cable cutting, stripping and injection in one workstation, an improvement in efficiency is accomplished [25].

2.3.5 Automation applied to Bowden cables production

Automation systems useful for the scope of this work

The automation of currently manually performed operations is often achieved by using different types of automation systems, such as pneumatic or electrical cylinders for several types of actuators controlled by a PLC (Programmable Logical Controller), using sensors and mechanical devices. There is a high diversity of standardized automation components and accessories, which must be a priority factor in the design of automated systems.

Control system

Control system that reads the sensor's state and links it to the actuator elements is needed. The information that is collected by reading the sensors and the logics programmed inside the microcontroller are making it possible to put actuators to work in a predefined way.

Sensors

There are multiple sensors on the market to detect a position or action that has been carried out. In Table 6 it is possible to see some commonly used sensors combined with basic automation solutions.

Table 6: Common types of sensors.

Type of sensor	Description
Inductive sensor	Sensor-based on the variation of the inductance. They detect ferrous metal parts, such as steel.
Capacitive sensor	Sensor-based on the variation in capacitance. They detect ferrous and non-ferrous material such as wood, glass, plastic, …
Magnetic sensor	Magnetic sensors have the characteristic of performing an electronic drive through the presence of an external magnetic field, close to and within the sensitive area of the sensor, coming in most cases from a permanent magnet. These sensors may be sensitive to the two poles of the magnet, NORTH or SOUTH, or be sensitive to only one pole.
Ultrasonic sensor	These sensors are formed by a transmitter and a receiver that uses the frequency variation to detect the distance from an obstacle.

Analog or digital variables can be used in an automatic process to make decisions such as starting/stopping of a cylinder. The instrument that captures what happens in the process is called a sensor. The component that performs the task initiated by the controller is called an actuator. There is a wide range of sensors available on the market, but, for this project, the ones that will be needed are the implemented in the T-groves of the cylinders (Figure 28). These sensors are offered in compatibility with the required cylinder for the job.

Figure 28: Magnetic sensors (direct mounting) [29].

Actuators

Actuators are components that convert electrical, hydraulic or pneumatic energy into mechanical energy. Hydraulic and pneumatic actuators are driven by fluids in motion. Hydraulic actuators use oil as fluid while pneumatic actuators use air. These actuators can be linear or rotary cylinders. In this project, the forces that are needed are small and, therefore pneumatic components will be selected.

The pneumatic actuators are generally used in systems where high speed is necessary and where the final positioning does not need to be exact. The three basic variables for controlling these movements are the direction of movement, speed and strength.

Table 7: Some common types of actuators.

Actuators	Description
	Pneumatic actuators
Single-acting cylinders	This type of cylinder is driven from one side. The return is carried out by the use of a spring or an external force.
Double-acting cylinders	This type of cylinder can work in both directions. The forces that are produced are slightly different due to the section occupied by the piston rod.
Double-acting tandem cylinders	Tandem cylinders are built out of two axial cylinders joined in one.
Rotary vane cylinders	The rotary vane cylinders have a rotating vane providing angular movements up to around 270°.
Rotary rack and pinion type cylinders	This type of cylinder converts the linear movement into a rotational movement using a toothed gear.
Rodless cylinders	In rodless cylinders, the piston force is transferred to a guided slide car through tape. The movement is reversed by the introduction of a pneumatic signal in the opposite chamber moving the car in the opposite direction.
Rotary actuators engines	The rotary actuators transform pneumatic energy into a rotating motion, designated normally by pneumatic motors, with one or two directions of rotation.

Actuators	Description
Gripper	The grippers are used to manipulate objects (catch, move or release). They are self-centered and can be used to handle a wide range of objects.
Vacuum pads	The suction cups are used to transport flat or slightly curved surfaces by creating a vacuum.
	Electrical actuators
Direct Current Motors	DC motors are generally compact and maintain a constant torque over a wide speed range.
Step motors	Step motors are essentially a DC-motors, but with control over the axis displacement. Each angular displacement of the axis corresponds to the pitch, and operate in open-loop control in position and speed, and are easily interconnected, simple, low-cost control units. The torque, however, decreases with increasing speed.
Alternating current motors	Although widely used in various industrial applications, AC-motors only have been used recently in manipulator designs, especially linear motors.

The specific actuators needed for this project will be double-acting (Figure 29a) cylinders and a rodless cylinder (Figure 29b). Also the grippers (Figure 29c) were considered to manipulate the product.

a) b) c)

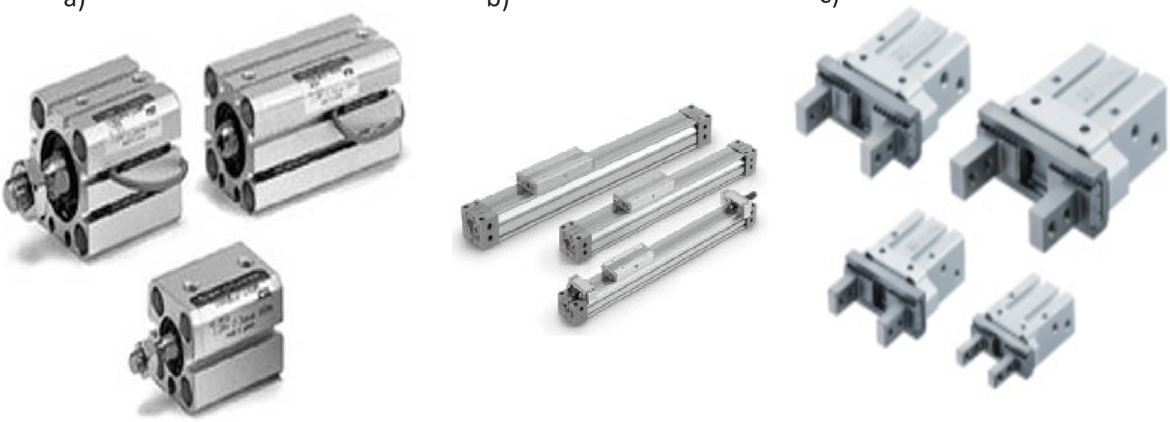


Figure 29: Double-acting cylinder (a) [30] , rodless cylinder (b) [30] and gripper fingers (c) [31].

COMPANY, PROCESSES AND PROBLEM CHARACTERIZATION

3 COMPANY, PROCESSES AND PROBLEM CHARACTERIZATION

3.1 Company characterization

The welcoming company, Fico Cables, Lda. was founded in 1972. Fico Cables is a manufacturer of mechanical components for commercial and industrial vehicles. The company belongs to the FICOSA group, which is active in 16 different countries.

- Ficosa International S.A. (FICOSA) [32]
  - The company: The company was founded in 1949 by Josep Maria Pujol e Josep Maria Tarragó in Barcelona (Spain). It was renamed to Ficosa International in 1987. The companies main activities are research, development, manufacturing and marketing of advanced technology vision, safety, connectivity and efficiency systems for the motor and mobility sectors.
  - The team: The Ficosa Group has more than 10 000 employees spread over Europe, North and South America, Asia and Africa.
  - Turnover: The company's turnover in 2015 was more than 1.112 million euros.
  - Innovation: The company is investing 6,5% of its yearly income in R&D. They have 14 R&D technology centers worldwide.
  - Global presence: As previously mentioned Ficosa is present in 16 countries in Europe, North and South America and Asia. The global activities can be seen in Figure 30.

Figure 30: Global activities of FICOSA INTERNATIONAL [33].

- Fico Cables, Lda.

  The company is situated in Rua do Cavaco, 115 Vermoin 4470-263 Maia (Portugal). The production plant and R&D center employ more than 1,400 professionals. Fico Cables main activities are making command cables for different applications such as door opening, handbrake, seating regulations. Another activity is the comfort systems. They are incorporated in the seats of the vehicle. Fico Cables are a supplier to big car manufacturers like Volkswagen.

3.2 Bowden cables manufacturing sequence and processes used

3.2.1 Bowden cables

Bowden Cables are mechanical components that make the transmission of motion possible between systems. They can be founded in different systems in vehicles such as opening doors, windows, seat's adjustment and many others. These cables have several manufacturing processes. It can have a braided metal cable that can be coated or uncoated, a plastic tube through which the metal cable circulates, that in turn is routed by an outer coated metal spiral tube, an outer damping tube, two Zamak-injected parts at the ends, and some plastic injected parts at the ends of the spiral and one or more elastomer injected parts for attachment to the car. Also, plastic can be injected onto Zamak injected parts to eliminate noise in operation [2]. You can see a few types of possible cables in Figure 31.

As described before, the Bowden cable is built out of different components that have different functions. A closer look at the whole production process of these different components and the assembly of the separate components will be presented.

Figure 31: 3 types of cables ZZH, IBT and IBT LASSO.[2].

3.2.2 Conduits

There are different conduits (spirals) used in the production of the Bowden cables:

- laminated;
- armed;
- twisted.

Laminated conduit

The production station of the laminated conduit is shown in Figure 32. They can have plastic tubes inside with the laminated steel around it. The machine is fed with laminated steel and the plastic tube. The steel is then turned around the plastic tube to make the conduit. The sub-product is then caught in the storage “wheel” in front of the machine.

Figure 32: Production of laminated conduit.

The result of an uncoated laminated conduit after cutting is shown in Figure 33.

Figure 33: Uncoated laminated conduit.

Armed conduit

The second produced conduit is the armed conduit. This conduit has the same inner tube but the metal around the tube is constructed by 17 wires turning around the tube. The turning wheel with 17 wires can be seen in Figure 35. An example of an armed conduit can be seen in Figure 35.

Figure 35: Production of the armed conduit.

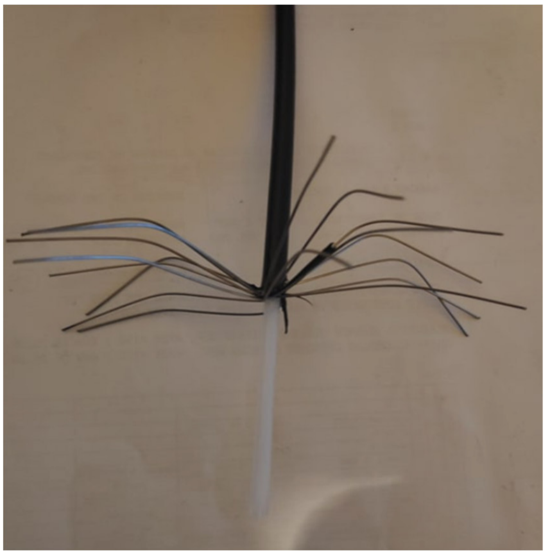


Figure 35: Armed conduit.

Twisted conduit

The twisted conduit consists of 16 wires compared to the 17 wired of the armed ones, and is constructed by twisting the 16 wires around the internal tube.

The conduits can also be coated with polymer over-injection (Figure 36). The production process for all three different conduits follows the same process, only the wiring process is different. Feeding of steel and internal tubes, then the machine produces the desired wiring. After the wiring machine, there can be a polymer coating by extrusion process (Figure 36), being cooled down in a water bath over a certain length. Then the conduit is collected at the end of the working station. After these operations, the conduits will be cut on the desired length for the specific product specification.

3.2.3 End of conduits

The end of conduits can be accomplished in three ways: overmoulding, punching and welding. The reason why there are different ways is depending on the necessary tensile strength, water tightness, etc. In Figure 37 it is possible to see the injection machine used for overmoulding.

Figure 36: Polymer over-injection of the conduit.

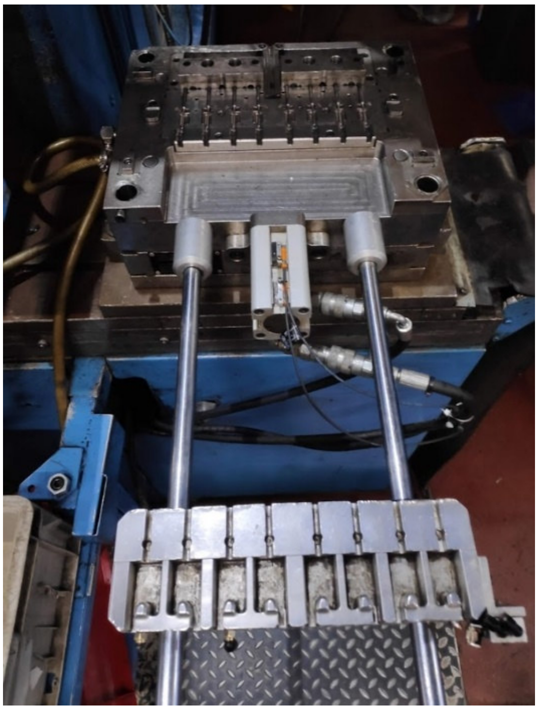


Figure 37: Injection machine with mould and jig.

3.2.4 Steel cable

The steel cables are cut on the length that is necessary for the different types of Bowden cables. This cut is usually performed by abrasive discs at high-rotation or using electrical rsistance, taking advantage of a system like the spot welding, where the elevated intensity of current produces the cut od the steel cable. The tip of the steel cable will be subjected to a hammering process in order to produce the mushroom, which is usually controlled, because this is a critical process in order to ensure the tensile strength that the Bowden cable needs to support.

3.2.5 End of steel cable

The end of the steel cable can be an injection of Zamak or steel. Some endings are not possible to make through Zamak and that is why there are steel endings as well. If a Zamak ending is preferable, it is important to know that a mushroom should be produced before the injection. This is necessary to preserve enough contact surface for the Zamak injection as discussed earlier. These two processes are done at the same workstation, as can be seen in Figure 38.

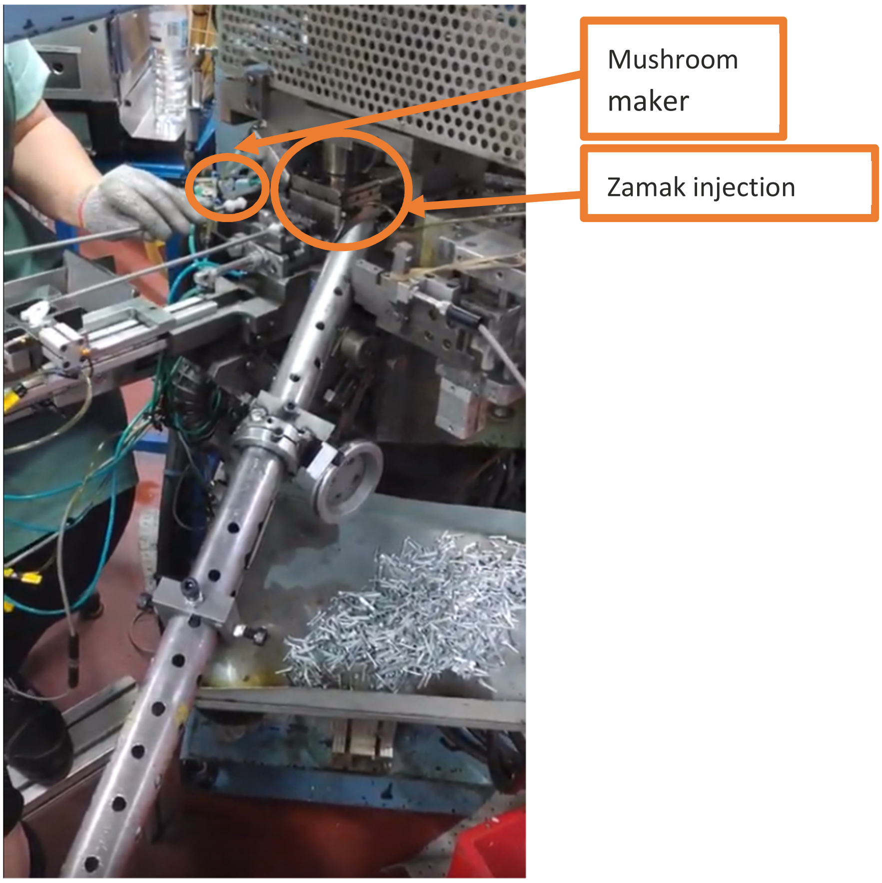


Figure 38: Mushroom + Zamak injection.

3.2.6 External tube

An external tube is put on the conduit to reduce the sound inside the car. This is done manually or with the help of compressed-air (Figure 39). This depends on the fitting of the external tube on the conduit. The external tubes are produced by external suppliers.

Figure 39: External tube mounted on the conduit via compressed-air.

3.2.7 Grommet

The grommet (Figure 40) is put on some of the cables to ensure that the water is not running in from outside of the car to the inside. These are produced by external suppliers.

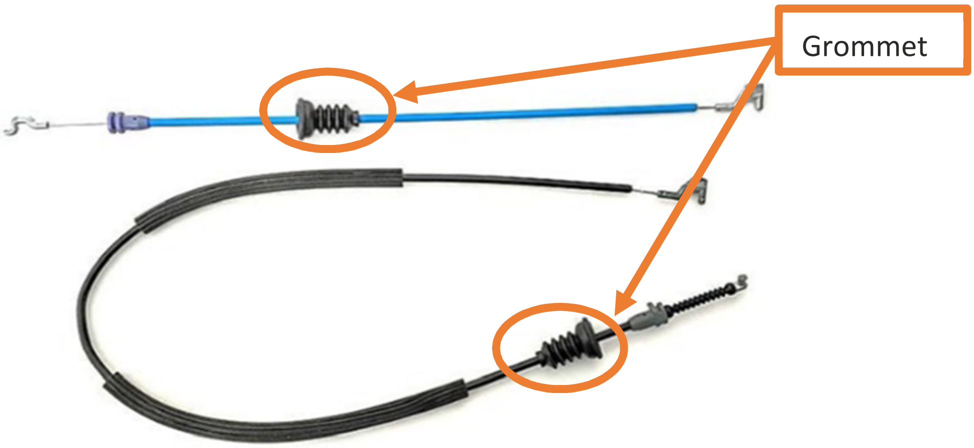


Figure 40: Examples of grommets on Bowden cables.

3.2.8 Manufacturing process

The manufacturing process described is the process fixated on the conduits that are considered in our project.

The whole manufacturing process of the Bowden cable is built up in different working stations as earlier described (Figure 26). The process is thus not fully automated. The manufacturing process begins with the manufacturing of the appropriate conduit (laminated/twisted/armed). This is done with an internal plastic tube where metal is spun around. Then, it is going through a polymer injection unit that produces a coating around the conduit. After that, there is a cooling bath to make sure the coating is dry before collecting the produced conduits in a buffer. This process is at the moment fully automated (Figure 36).

The produced conduits are then transported to another place on the site, closer to the rest of the workstations. There is a cutting machine available which cuts the conduits at the appropriate length. It also leaves some marks behind to make it easier in the coming process to clamp.

After, the conduit is moved to the injection station where the end of the conduit is injected over the conduit (Figure 37). There is currently one operator who puts in the conduits before the injection and takes out the conduits after the injection. The operator puts then the finished conduits in a box and the scrap in a different box. The box is then moved to another station where the steel cables are inserted. First, the steel cables are cut on the desired length and afterwards moved to the desired workstation, where the mushrooming in the steel cable is produced, checking the mushroom and the first end of cable injection (Zamak) on to the steel cable (Figure 38). The steel cables are then inserted in the conduit and then have a new cut on a new length with a new reference (end of conduit) to assure conformity (Figure 41). The second

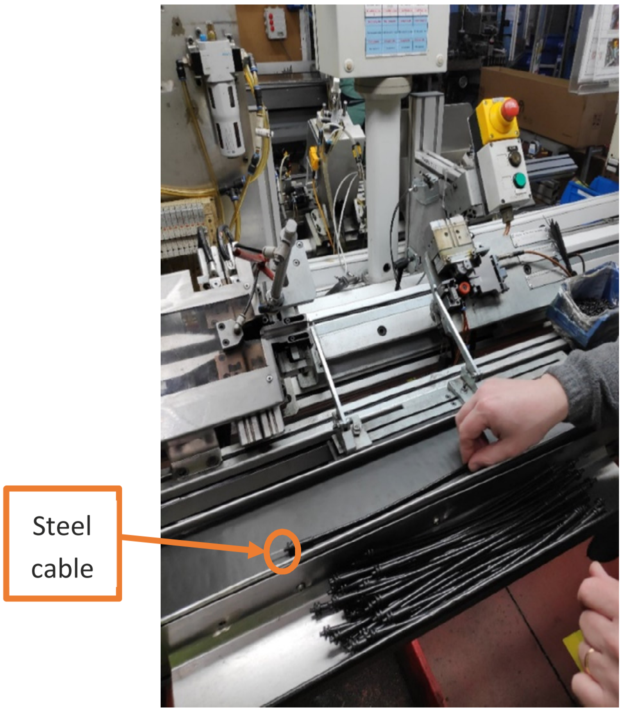


Figure 41: Second cut for the steel cable.

mushrooming, checking the mushroom and the second end of steel cable injection is then happening. This process is done by one operator who puts the steel cable into the mushrooming machine and the injection machine.

The only thing that is then left to do is a complete check of the produced Bowden Cable, checking the length and the tensile strength using a test bank (see Figure 42). One operator is putting all the Bowden cables in manually. The Bowden cables are then assigned OK and NOK after the test.

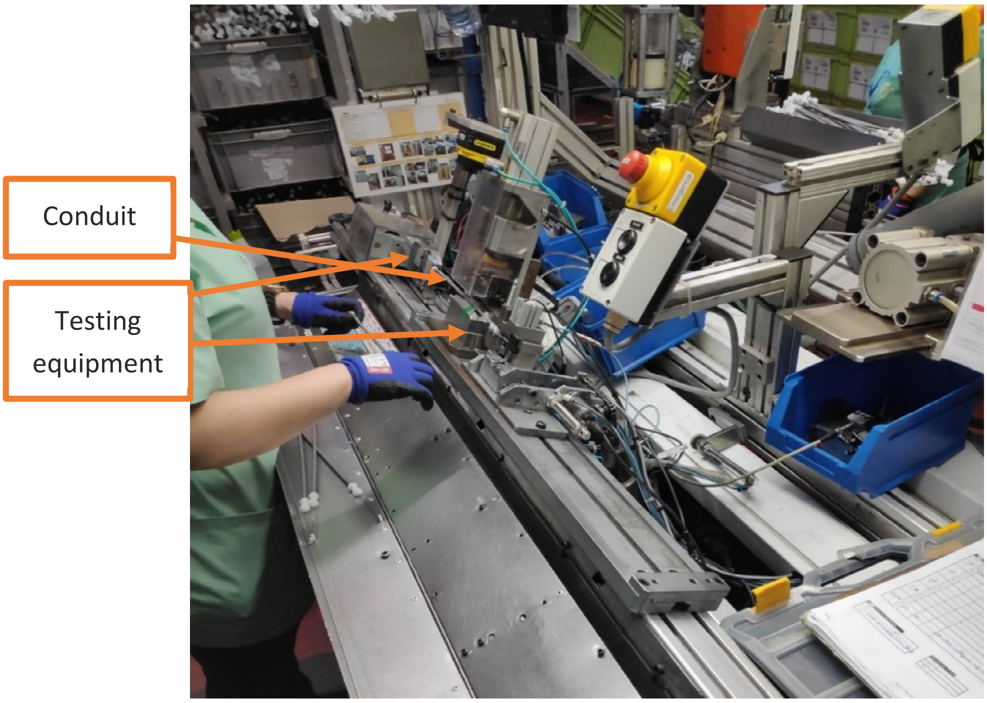


Figure 42: Testing bank for the Bowden cable.

For some Bowden cables, there is also the necessity to have an external tube or a grommet. The external tube can be put on the conduit manually or with the help of compressed-air (Figure 39). This is accomplished by one operator. The same thing is happening for the grommet, this is assembled manually by one operator. These operations are happening before the second injections.

3.3 Problem characterization

3.3.1 Current situation

As described previously, the production of Bowden cables is not fully automated. There are 9 different workstations. The sub-product is always transferred between those workstations. At the working station where the end of the conduit is injected on the conduit, there is one operator for one injection machine at the moment. The current machines have the capacity to inject eight end of conduits at once (Figure 43).

It can be clearly seen that the conduits are kept in the correct position in the jig by using magnets (Figure 44). The conduits have the possibility to have different lengths, so it needs to be possible to change the position of the jig. In the current system, the screws are on the bottom side of the jig. This way of fastening is not maintenance friendly or ergonomic for the operator while removing. At this moment, the operator needs to do the following tasks: put in the conduit, use the operating buttons, injection of the end of the conduit and take out the injected parts manually.

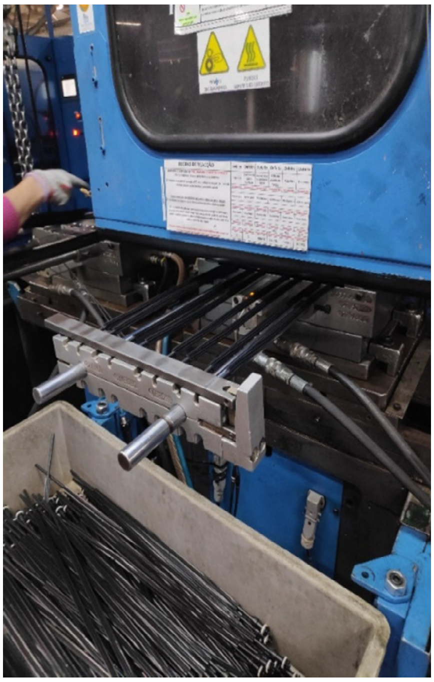


Figure 43: End of conduit injection jig 1

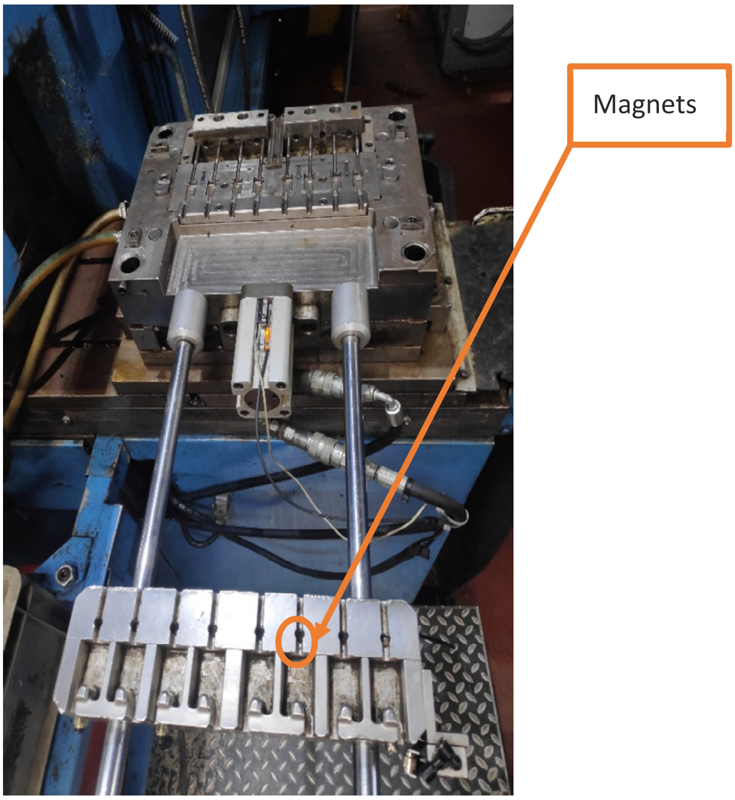


Figure 44: End of conduit injection jig 2 (current situation).

The first proposition for the project was to make a manipulator for these older injection machines. However, the scoop of work changed as the company is investing in new injection machines (Babyplast®).

Future machines will look quite different. Ficosa cables ordered new machines which are smaller and are consuming less energy. Though, the capacity of the new machines will only be four ends of the conduit injections at the same time.

3.3.2 Future outlook of the company

The future outlook of the company is to have one operator at two of the new injection machines (Babyplast®) (Figure 45). The new injection machines (BabyPlast®) have only a capacity of four injections of end of conduits at once compared to eight of the older injection machines (Fiser®). Thus, a way to take out the overmoulded conduit and the scrap from the mould and put them into storage boxes needs to be found. Then, one operator would be able to put in the conduits manually in both the injection machine while the manipulator would be taking care of removing the overmoulded conduits and the scrap from the mould. This must all be made in a safe relation with the operator. This means that it will be needed to foresee some light screens or fences to make the whole process safe for everyone.

The whole reason behind the acquisition of the Babyplast injection machines is that they are smaller, consume less energy and are more maintenance-friendly.

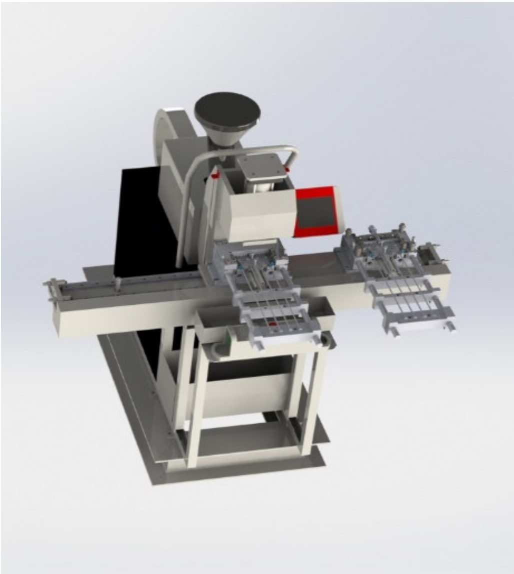


Figure 45: Babyplast injection machine.

DEVELOPMENTS AND RESULTS

4 DEVELOPMENTS AND RESULTS

4.1 Practical approach followed to solve the problem

The structure that has been followed in practical terms to solve the problem can be seen in Figure 46.

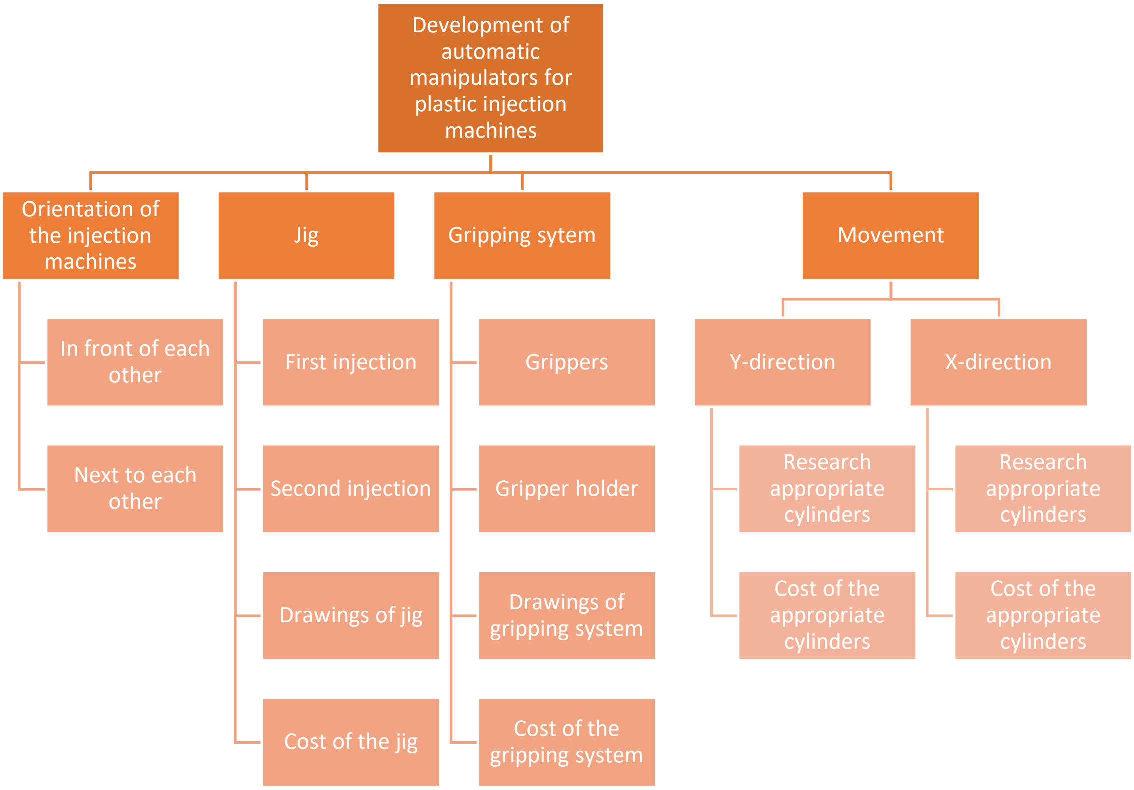


Figure 46: Practical approached followed to solve the problem.

4.2 Brainstorming about possible solutions

4.2.1 Description of the different solutions

Orientation of the injection machines

The first thing that needs to be decided on, is how the injection machines need to be orientated. The two considered options are next to each other (Figure 47) and in front of each other (Figure 48). The numbers mentioned in Figure 47 and Figure 48 are presenting the workflow the operator would be following.

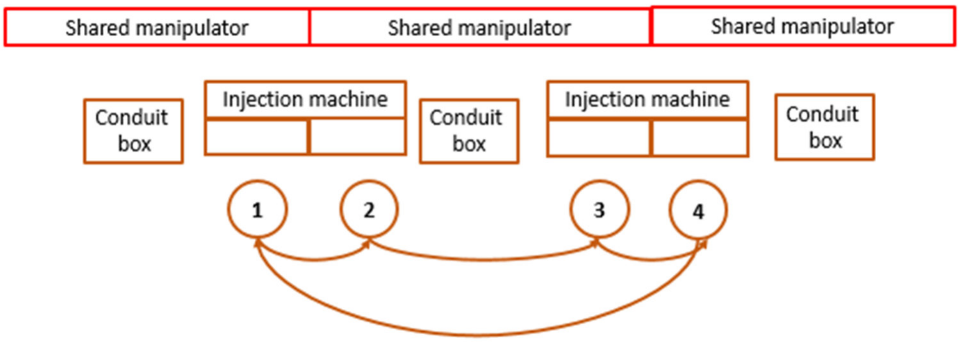


Figure 47: Diagram of the injection machines next to each other.

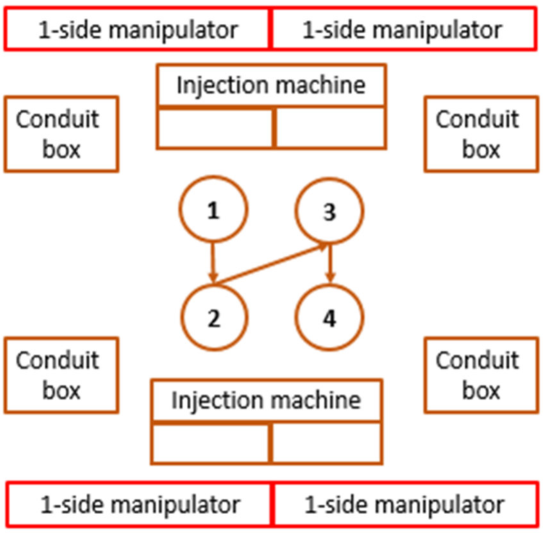


Figure 48: Diagram of the injection machines in front of each other.

Jig

The design of the jig is split up in two designs, a design for the first injection (Figure 49) and one for the second injection (Figure 50). For the first injection, there is no need to have a cut-out shape of the end of conduit. A cut out shape around the conduit is enough. For the second injection jig, it is necessary to have a cut-out form for the second injection. The jig needs to make sure that the conduit is kept in place during the injection of the end of the conduits.

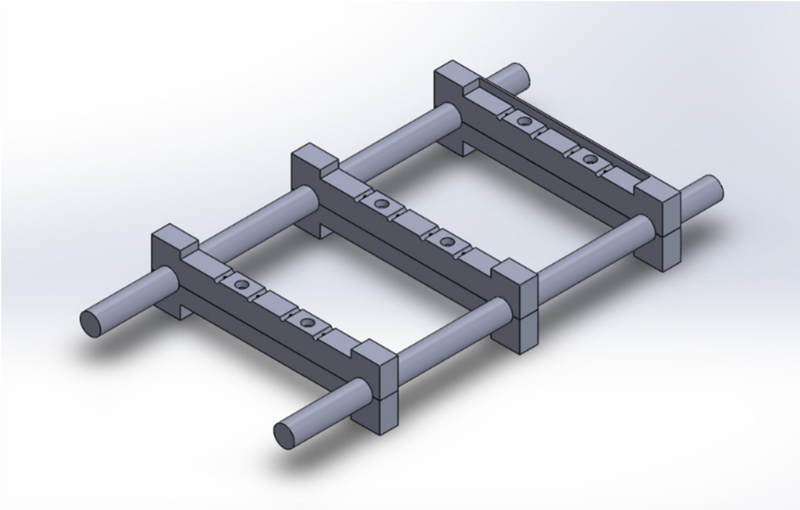


Figure 49: First injection jig.

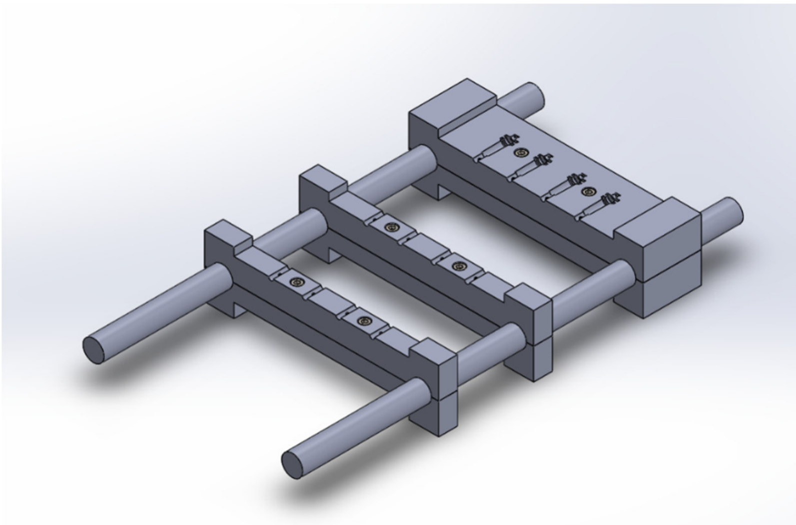


Figure 50: Second injection jig.

Gripping system

Before, discussing the concepts that were taken into consideration, some movements/adjustments need to be described, which can be made to the system to make it more flexible: forwards/backwards, left/right and up/down. These movements are described in Figure 52.

Grippers

The systems that were taking into account as grippers were a standard gripper from Festo, a compact scrap gripper system, a gripper designed based on a robust standard cylinder and a gripper solution that can clamp four conduits at the same time, using only one cylinder. These systems can be seen in Figure 51.

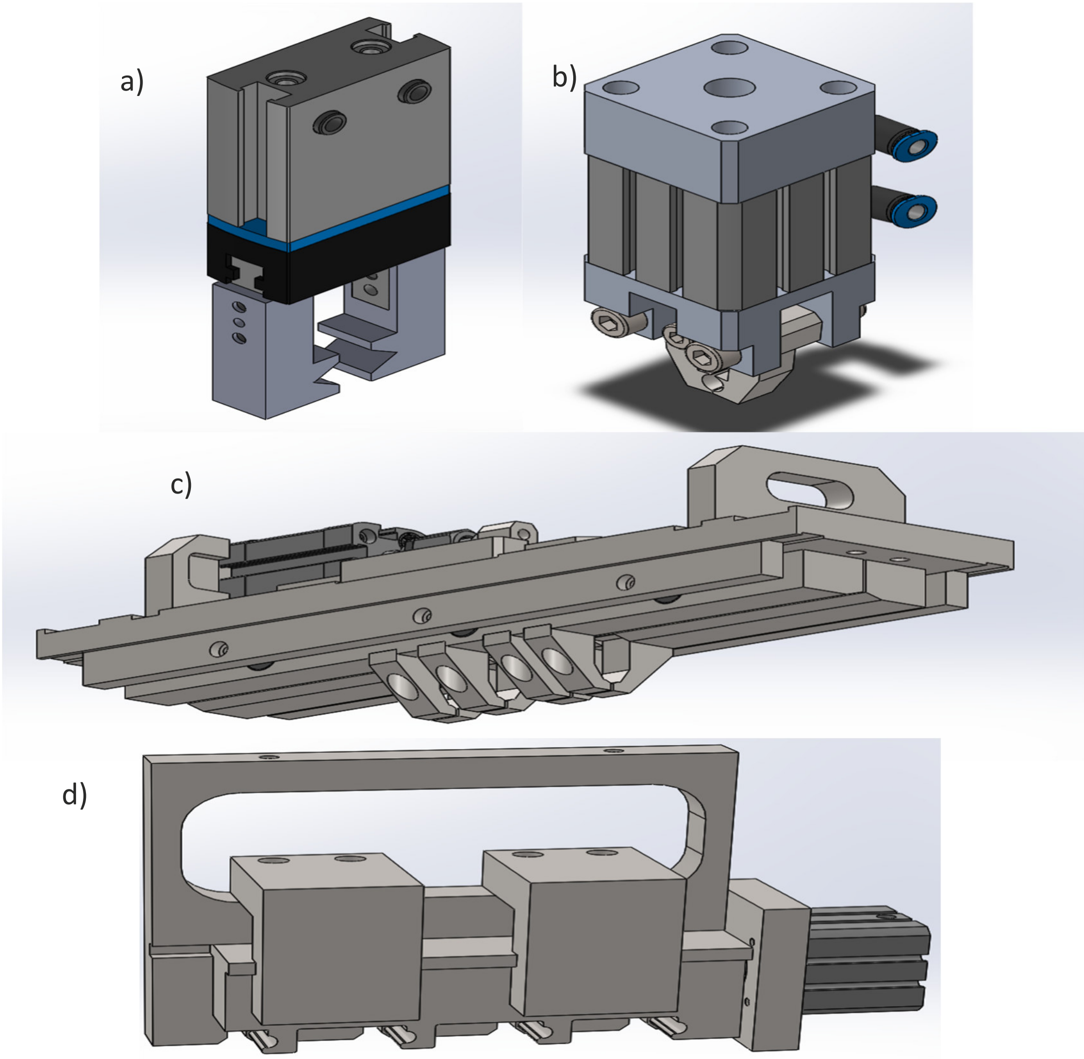


Figure 51: Grippers considered in the design a) DHPS-serie(FESTO) with designed clamps; b)CDQS-serie (SMC) with a clamping system; c) Compact scrap gripping system with the use of ADN serie cylinder (FESTO); d) Gripping solution with the use of an CDQS-serie cylinder (SMC)

Gripper's holder

The final design of the gripper's holder was not created at one time. Some varieties have been created during the development process. The first basic concept was based on the standard clamping cylinders (DHP-series) from Festo (Figure 52).

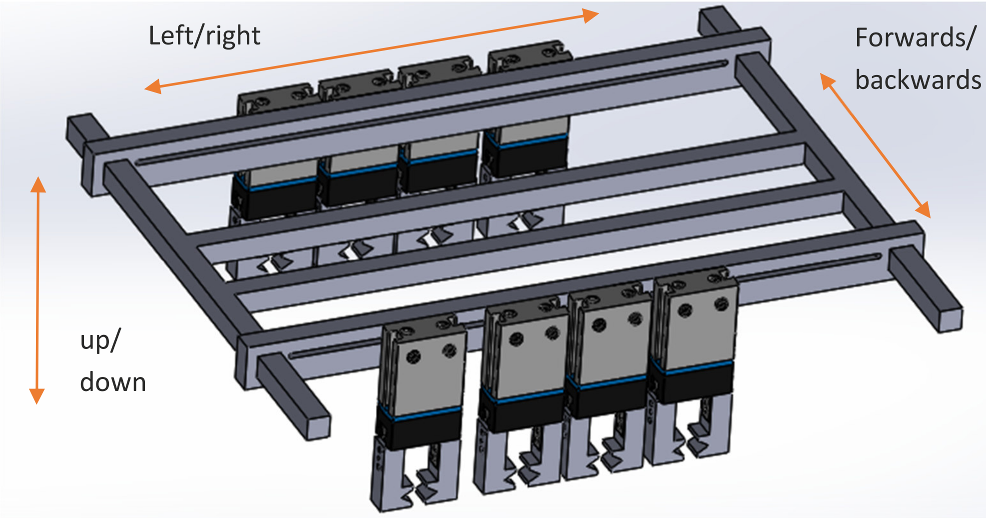


Figure 52: First initial concept for the gripper holder.

The second concept was a more robust concept with a special gripping system for the scrap removal. The scrap gripper is fastened in the same way as the conduit grippers in this concept. All the grippers can be moved separately to left/right and up/down (Figure 53).

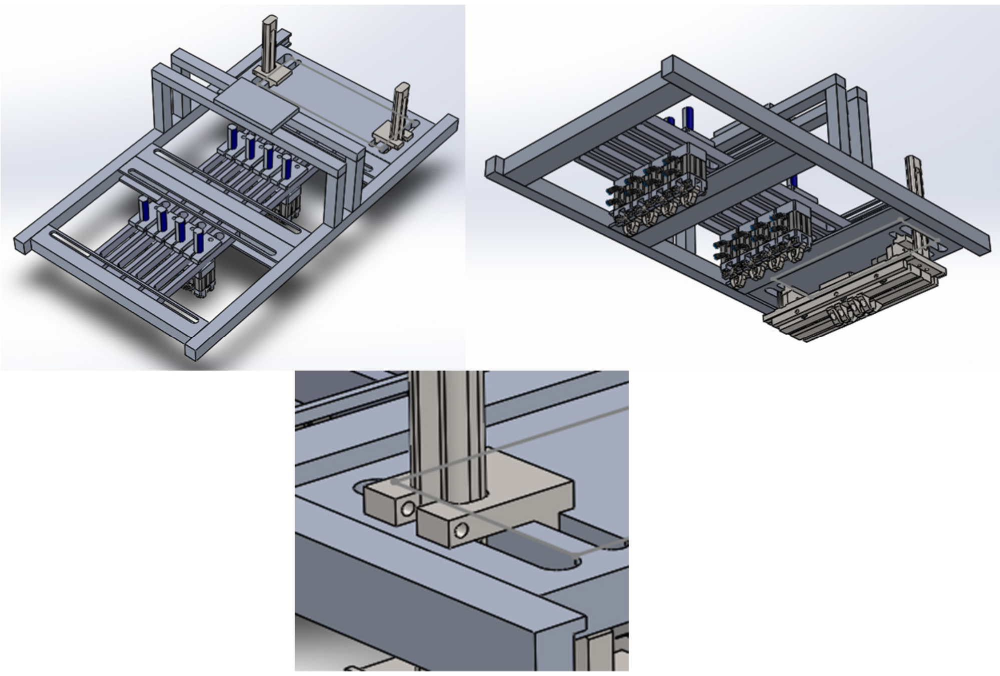


Figure 53: Second concept for the gripper's holder.

The third concept is already more detailed and it is possible to see that the big difference is in the fixed distance between the grippers. They are still separately movable up/down and forwards/backwards, but not left/right anymore (Figure 54).

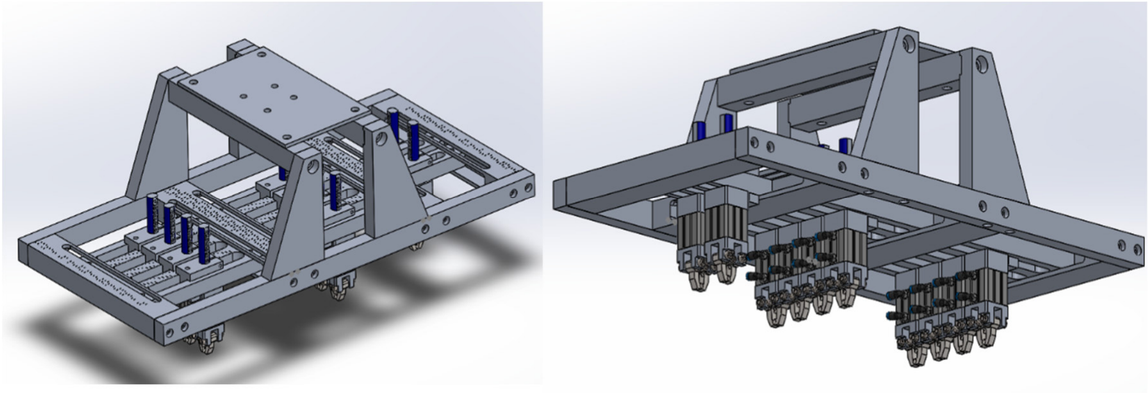


Figure 54: Third concept for the gripper holder.

The fourth concept is similar to the third one. The difference is that the system is working here with a bridge to make the movements of the cylinders possible. This way, it is possible to move the four cylinders at the same time (Figure 55).

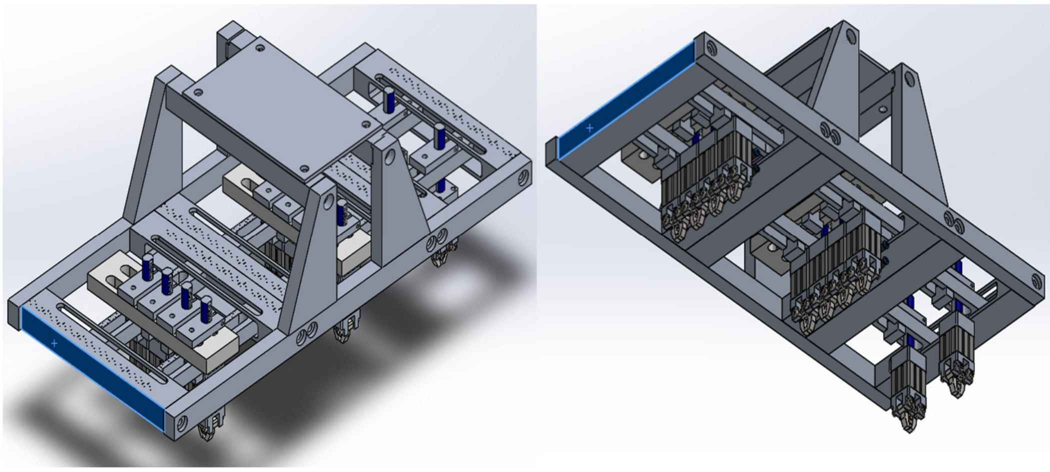


Figure 55: Fourth concept for the the gripper holder.

The fifth concept is again similar to the third and fourth ones. The difference here is that there is another bridge. The grippers are fixed in distance between each other and a bridge is making it possible to get them move altogether to the right or left. But, each gripper can be adjusted to go up/down separately (Figure 56).

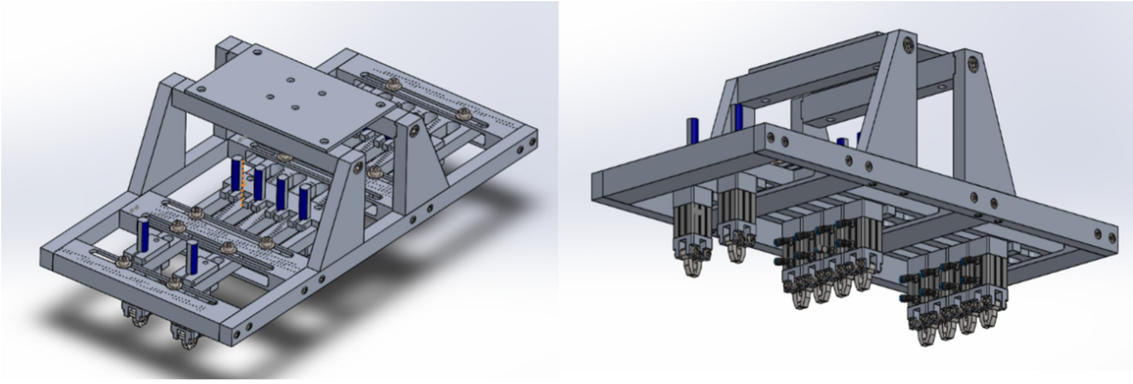


Figure 56: Fifth concept for the gripper holder.

The sixth concept (Figure 57) is different: after discussing with the company, it was concluded that the center distance between the conduits will always be the same (36 mm). Thus, the holder of the gripper can have a fixed distance. The grippers still have the possibility to move forwards/backwards over a certain distance due to the additional added holes.

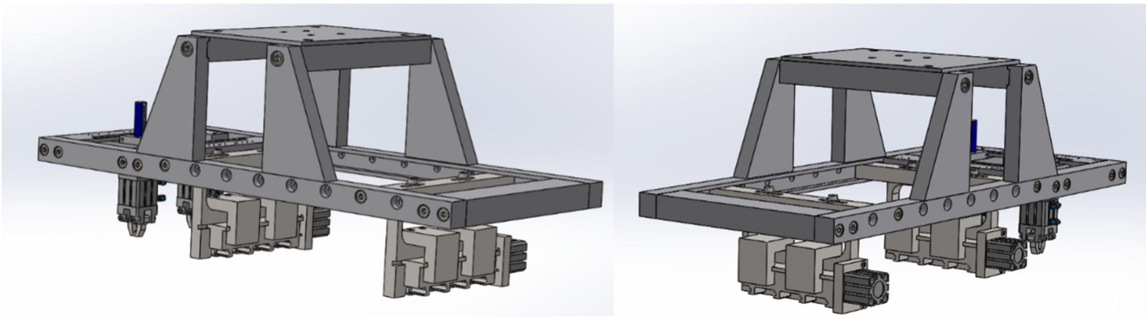


Figure 57: Sixth concept of the gripper holder.

Cylinders' movement

A first concept for the cylinders' movement is a combination of cylinders found in Festo catalogue. It is possible to see the combination between the SLM-series and SLE-series in Figure 58.

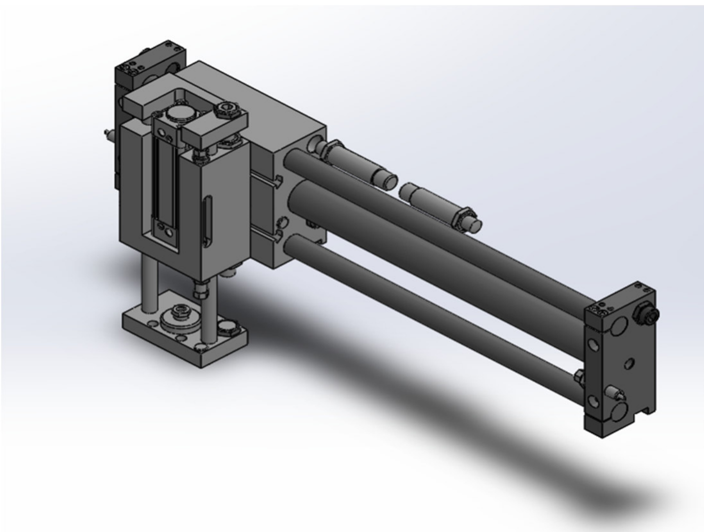
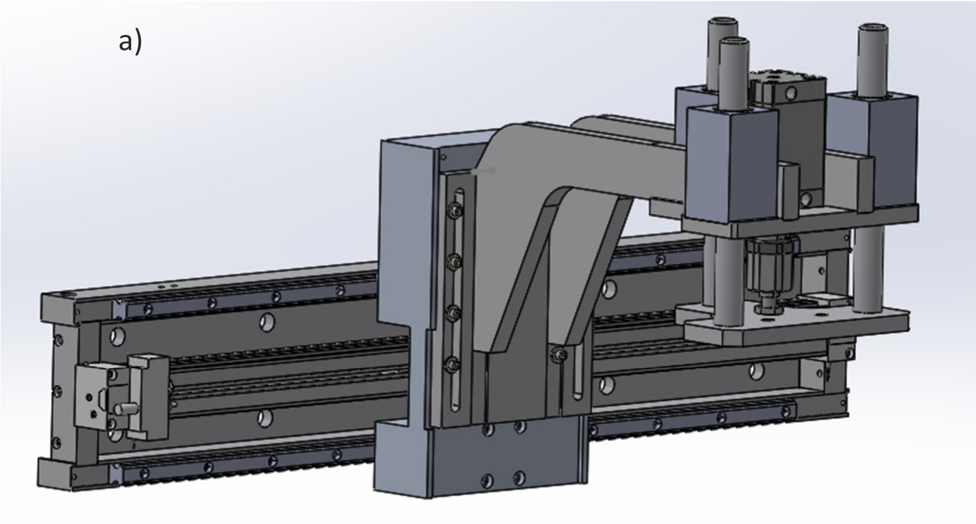


Figure 58: Combination of SLM and SLE Festo's cylinders.

The second concept is based on basic cylinders with equipment designed to make the desired movements possible. It is built out of two guiding rails and two cylinders that make the two desired movements possible. In concept a), the holder of the lever arm is built out of one part of aluminium while in concept b) the holder of the lever arm is built out of 3 separate parts, two parts in aluminium and one in steel (Figure 59).



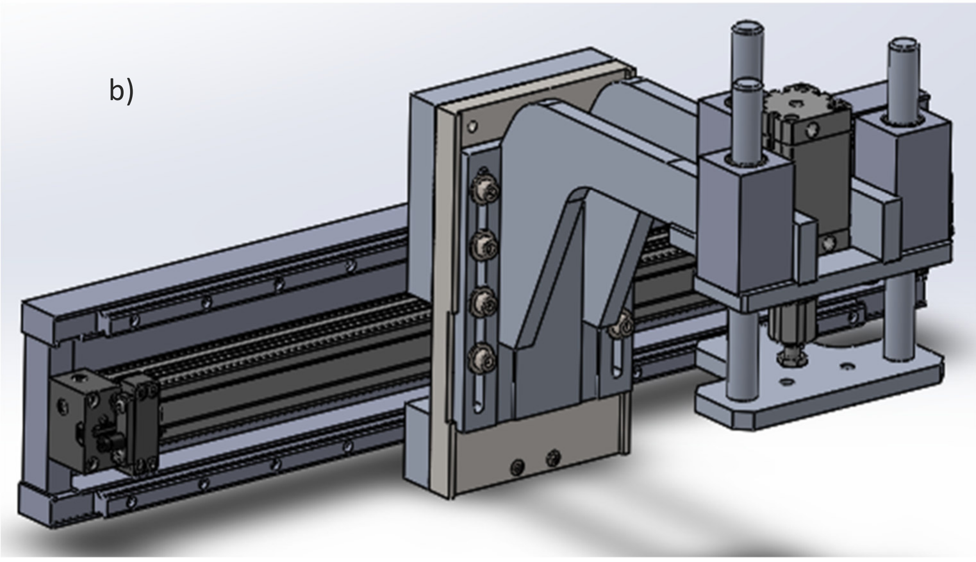


Figure 59: Second concept for the movements a) holder of the lever arm in one part b) holder lever arm in 3 parts.

Frame

The frame (Figure 60) is designed around all the previous components. It needs to have space for the storage boxes for the conduits, scrap boxes, assembling of the guided rails and cylinders needs to the system.

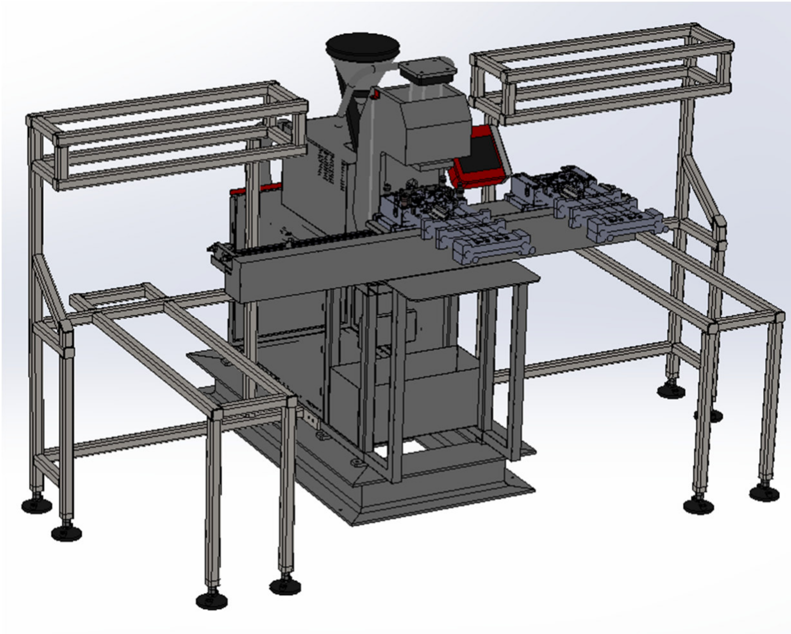


Figure 60: Frame adopted to the final solution

4.2.2 Critical analysis of each possible solution

The orientation of the injection machines

A. Next to each other

Referring to Figure 47, it would be easier to share a manipulator when the machines are next to each other. We could still think about sharing a manipulator between two workstations but this can cause troubles in cycle times. The two workstations should then start at a specific time and also the operators need to maintain the same pace for the rest of their shift. We can discuss the fact that the manipulator will not be in use all the time, but this is the best way to avoid problems in cycle times.

B. In front of each other

Referring to Figure 48, this is the best way for the operator. He only needs to turn around his axis to put in conduits in the other injection machine. The time needed to move sideways to the other injection machine is eliminated. When the machines are in front of each other, sharing a manipulator is not an option.

Jig

Referring to Figure 49 and Figure 50, it is possible to see that the designs are quite similar. For the second injection, it is needed to have a cut-out shape to make sure that everything is kept in place and correctly aligned in comparison with the first injection. The force that keeps the conduits in the jig, is caused by magnets put inside the jig. One of the important details of the jig for the second injection is that it needs to be long enough. This way, there is enough support for the end of the conduit and stays correctly aligned.

Gripping system

Gripper – *DHPS series*

The easiest design of a gripper is the parallel gripper from the Festo's DHPS-series (Figure 51a). They can be perfectly used as grippers for the conduits. The DHPS-series grippers are vulnerable to damage and quit expensive. It is also needed to design some clamps to put over the grippers, which can pick up the shape of the conduits.

Gripper – CDQS series

The gripper is built up from a basic linear cylinder. The linear movement of the cylinder is translated into a rotating movement which makes it possible to clamp the conduit. On top of the basic cylinder, there are some parts designed that make this possible. These kinds of grippers were previously used inside FicoCables. This designed system is a cheaper and more robust solution compared to the 'simpler' but more expensive and vulnerable design of the DHPS grippers. Also, the concept that was created to clamp four conduits with one cylinder was made using the CDQS cylinders.

Compact scrap gripping system

The compact scrap gripping system was designed in case there was a lack of space. Here, one cylinder causes four clamps to close or open at the same time. By using only one linear cylinder, it is possible to save again some amount of money on cylinders or parallel grippers. However, the system is quite rough.

Gripper holder

First concept for the gripper holder

The initial concept for the gripper holder is designed around the parallel grippers from Festo. It is possible to move the gripper sideways in the desired position but not in height (up/down).

Second concept for the gripper holder

The second concept for the gripper holder is a combination of the CDQS-series and the compact scrap gripping system. The compact gripper system and holder would create a large mass center in front which does not seem feasible. The bridge over the cylinders could cause high stress in the corners. All grippers can be moved separately sideways (left/right) and in height (up/down). The separate moving of the cylinders is not exactly necessary as the center distance between the conduits will always be the same.

Third concept for the gripper holder

The third concept removes the special compact gripping system and replaces it to all grippers of the CDQS-series. Together with a fixed plate where the cylinders are mounted inbetween resulting in the same center distance between all grippers. Grooves on the side were implemented, thus, the operator has a reference to setup the grippers easily. Another scale is added to have a reference concerning the height of the grippers. All grippers still need to be fastened one by one.

Fourth concept for the gripper holder

The fourth concept is similar to the third. The biggest change is the use of a bridge that makes it possible to move the grippers forwards/backwards in a faster way, decreasing the setup time. The grippers can still be modified separately in height and center distance between them.

Fifth concept for the gripper holder

The fifth concept uses ideas of all the previous concepts. It uses the advantages of a bridge (quicker setup time), a fixed plate to ensure the center distance between the grippers, keeping in mind that the grippers can still be modified in height.

Sixth concept for the gripper holder

The sixth concept has a fixed distance between the centers of the conduits. The grippers can still be moved forwards over fixed distances through the bolting holes to adjust them to the length of the conduit. They can be moved left/right a little, to solve misalignment.

Cylinders' movement

First concept

The first concept was based on a combination of SLE and SLM cylinders from Festo. This combination is perfect for XY- and XYZ-systems. The drawback of using these cylinders is that they are more expensive than standard cylinders and more vulnerable to impact.

Second concept

The second concept is based on the use of basic cylinders and guide rails. To implement this solution there was the need to design some parts. The second concept has two varieties. One of them is with the holder of the lever arm in one part, the other is built out of three parts with different materials (steel+aluminium) improving the strength. This concept was made as in the past, there have been some problems with the threads after a number of switches.

Frame

The frame is designed around the whole solution to make it fit perfectly. The frame must be strong enough to avoid vibrations and deformation (bending). These vibrations could harm the equipment and deformation could imply the gripper system to not be correctly aligned anymore.

4.2.3 Selection matrix, parameters and weighting justification

After describing all the possible concepts considered for the design, SWOT-analyses were carried out to pick the best solutions.

Orientation of the injection machines

Picking the orientation of the injection machines seems like a simple decision but, it has a big impact on the rest of the design, as well as the ergonomic way of working for the operator in the future. After taking out the SWOT-analysis for both options (Figure 61 and Figure 62) and talking with a few employees about the ideas, the decision was made to go for the injection machines in front of each other.

This decision was mostly based on a more ergonomic way of working for the future operators of the injection machines. Only needing to spin around their axis to work further and no need to walk a short distance every time, can improve the awareness of the operator in the long run. This implies immediately more energy and focus for their respected work.

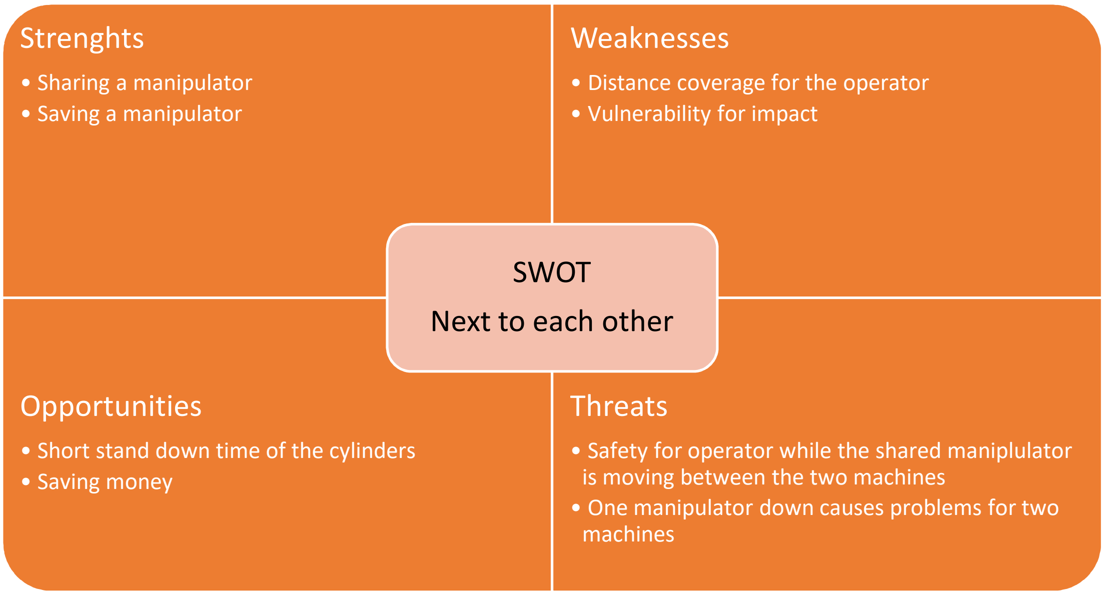


Figure 61: SWOT-analysis considering injection machines next to each other.

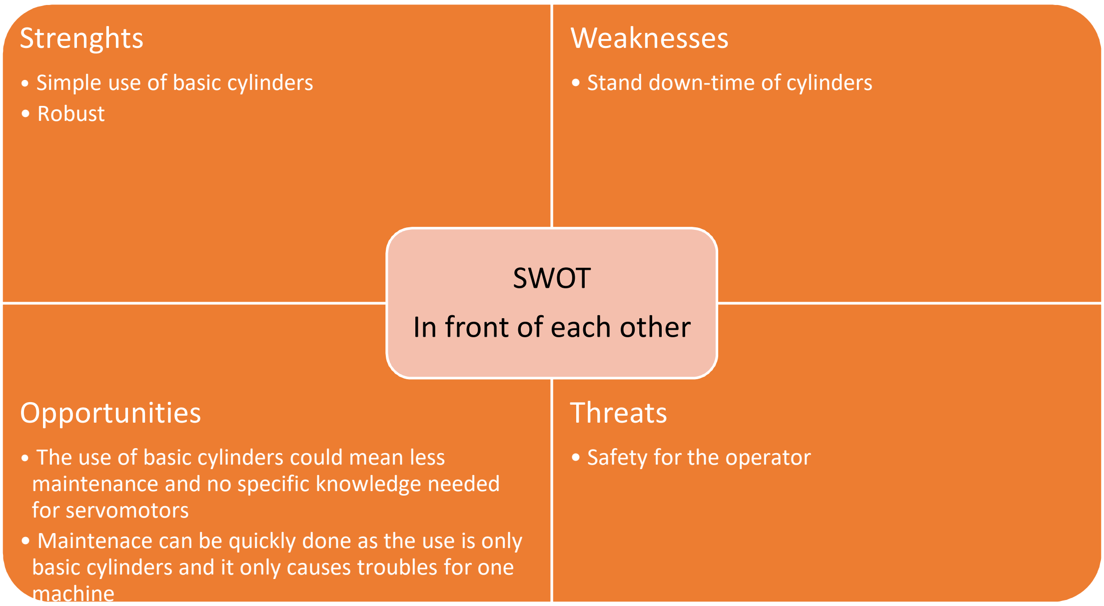


Figure 62: SWOT-analysis considering injection machines in front of each other.

Jig

The second design that needs to be questioned is the jig. This was straight forward as the design was based on the current ones used inside the factory. Only a few changes have been made to make an improved design. For example, the fastening bolt was put on top instead of on the bottom. Thus, it is more ergonomic for the worker who is going to change the jig.

Gripping system

Grippers

All the grippers mentioned could be used in the design. They would all be successful in taking out the conduits/scrap. Therefore, it is needed to compare them as much as possible. The most important factors to take into consideration are cost, maintenance, robustness, amongst others. Robustness and maintenance are related to each other as operators are sometimes rough with the equipment, it is needed to make sure that the equipment can have a hit and not going to fail after a small incident.

After considering the options in the function of the companies best interest (price, maintenance, etc.), it was chose a design for the cylinders where just one cylinder is necessary to clamp four conduits at the same time. It is a simple, cheap and robust way to have a good gripper system.

Gripper holder

After deciding to go with the gripper based on the CDQS cylinder, it is not necessary anymore to consider the first concept. The second concept is still taken into consideration because of the bridge design. But, the best solution is the sixth concept. It is reducing the number of cylinders needed to clamp the conduits. Thus, it is safe to say that by reducing the number of cylinders it is possible to reduce the cost, maintenance, set-up time, etc. That is why the sixth concept was chosen as the final concept. A SWOT-analysis (Figure 63) is carried out on this concept.

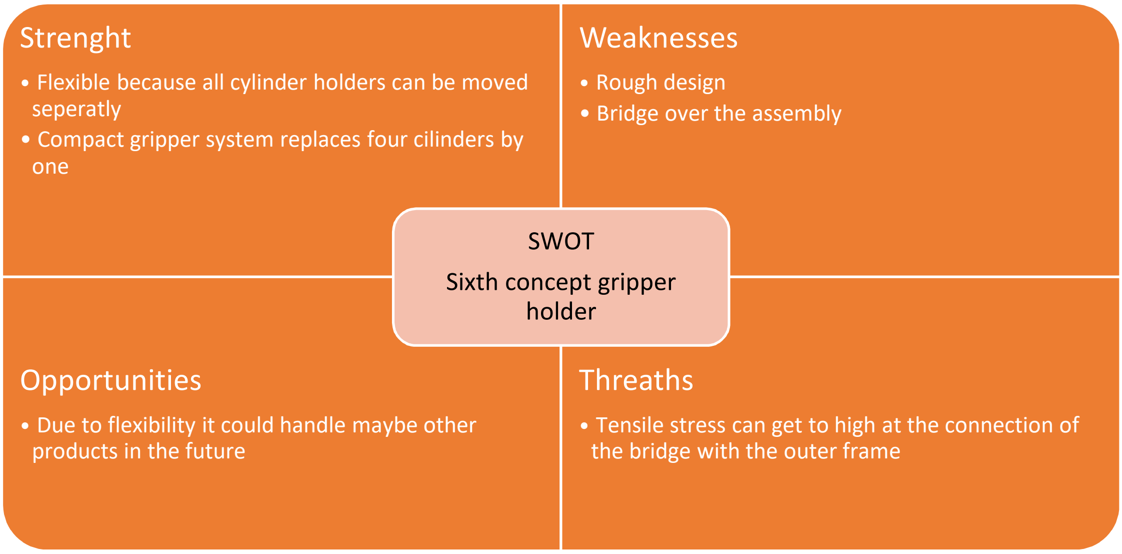


Figure 63: SWOT-analysis of the sixth concept of the gripper holder.

XY-manipulations

Two different systems were considered for the use of XY-manipulations: (a) the combination of SLM and SLE cylinders found in the FESTO catalogue, and (b) a design based on basic cylinders and guiding rails. A SWOT-analysis was carried out on both (Figure 64 and Figure 65).Out of these two options the basic cylinder + guiding rail was chosen. This was more favorable for the company in terms of maintenance and cost.

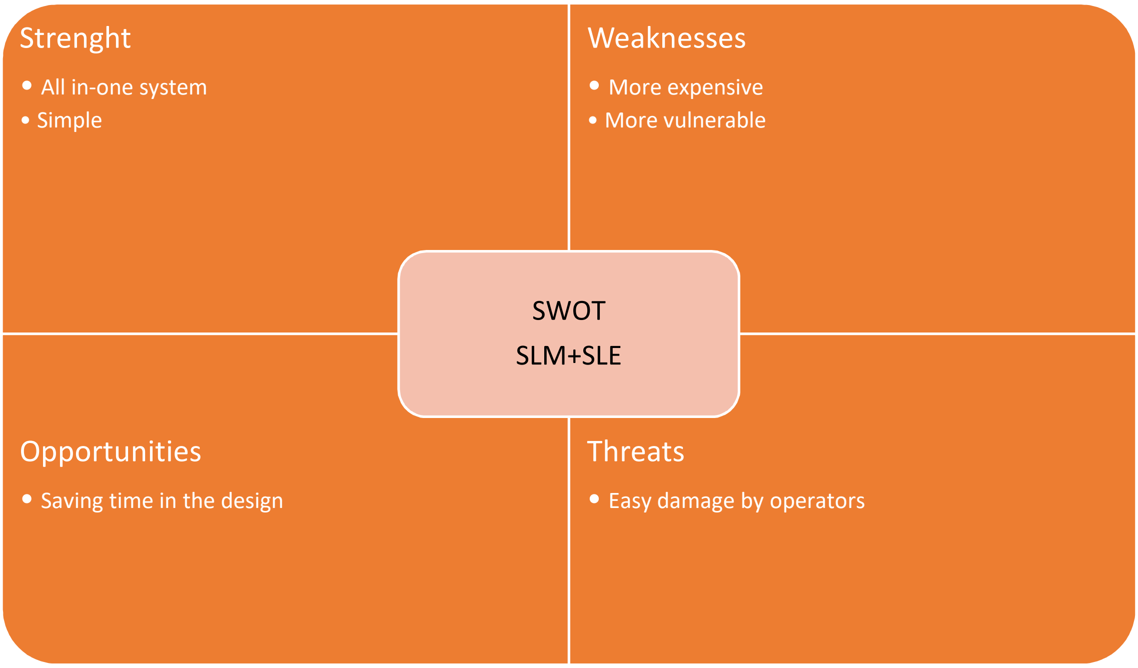


Figure 64: SWOT-analysis considering SLM+SLE cylinders.

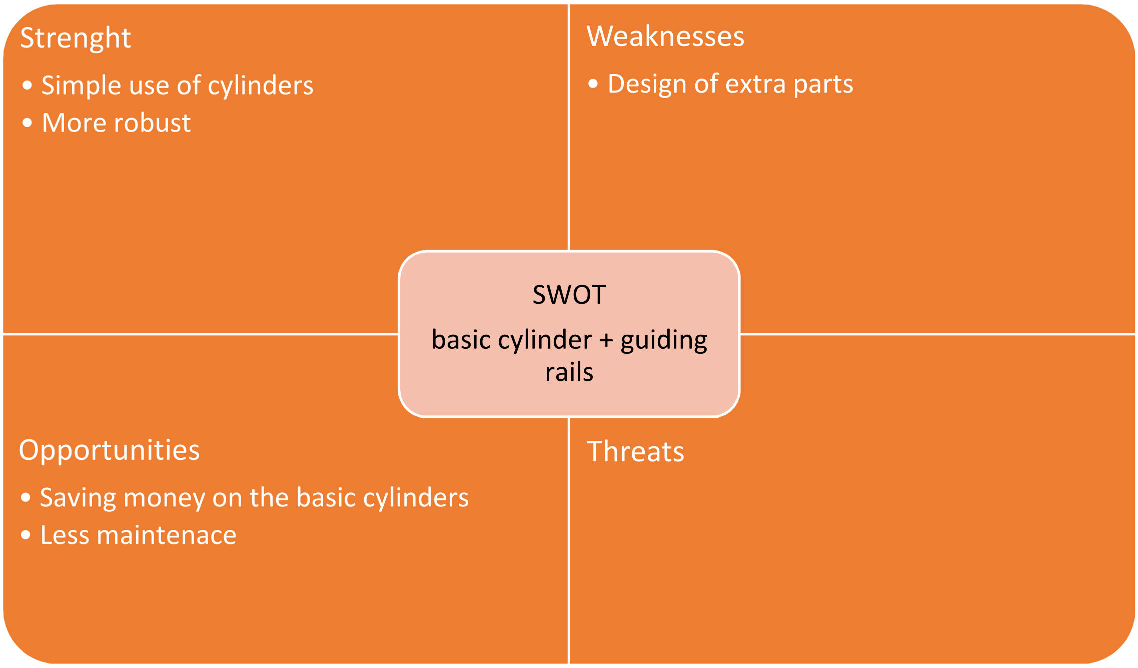


Figure 65: SWOT-analysis considering basic cylinders + guiding rails.

4.2.4 The main concept of the final solution

In this section, it will be described the final solution adopted more in detail. The problems starts again with the orientation of the injection machines. It was chose to put two manipulators and an injection machine in front of each other, as seen in Figure 66.

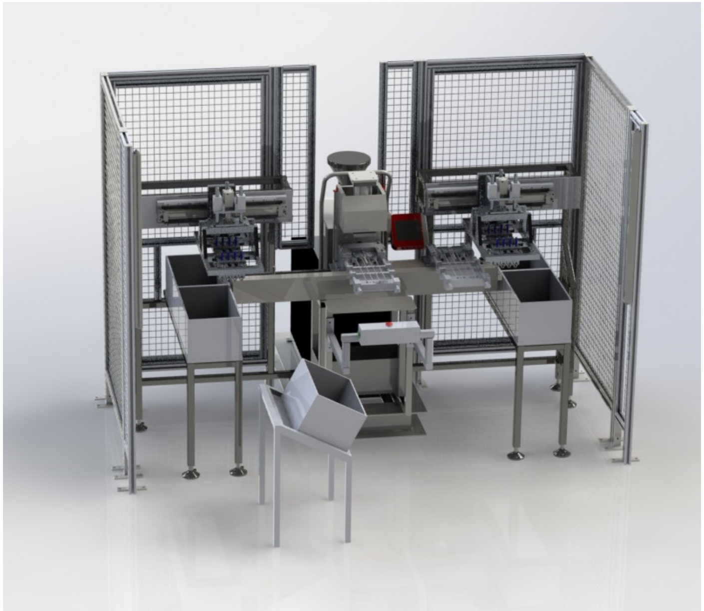


Figure 66: Assembly of the final adopted solution.

The first designs that will be discussed are the jig for the first and second injection (Figure 67).

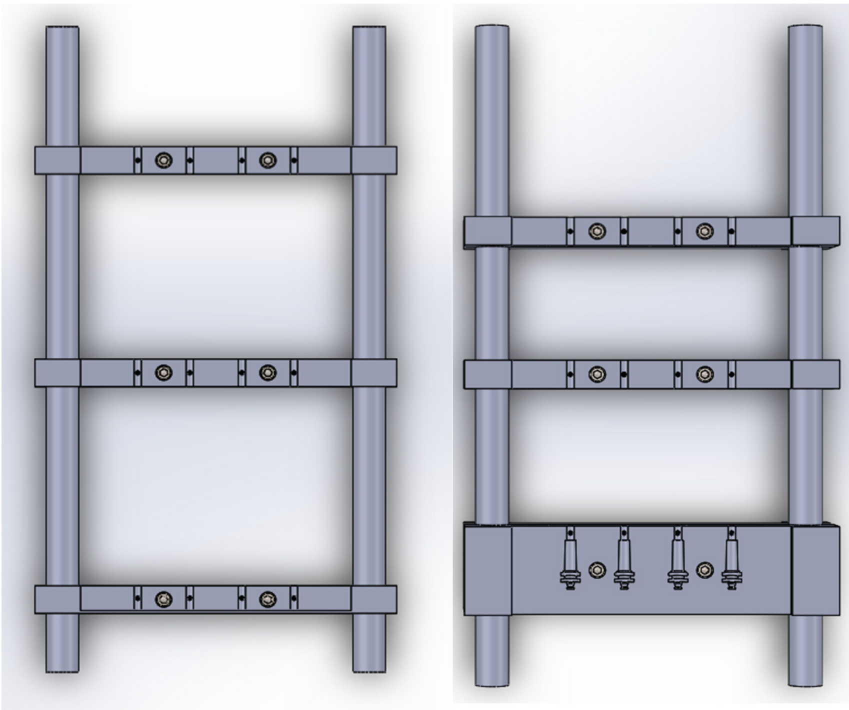


Figure 67: Top view of the jig for first and second injection.

The holders can be adjusted in position by removing the fastening bolts. They are built in two halves, fastened by two socket head cap screws in the middle. In Figure 68 it is possible to see how the support holders for the conduits are built up. They have been implemented in both designs two times, to assure enough support that the conduits will not deform. The end of the conduit holder for the first injection is practically the same as the support holder. The difference is that there is a stop at the end to assure that the conduit cannot move anymore (Figure 69a). The end of the conduit holder for the second injection has the shape of the injection (Figure 69b).

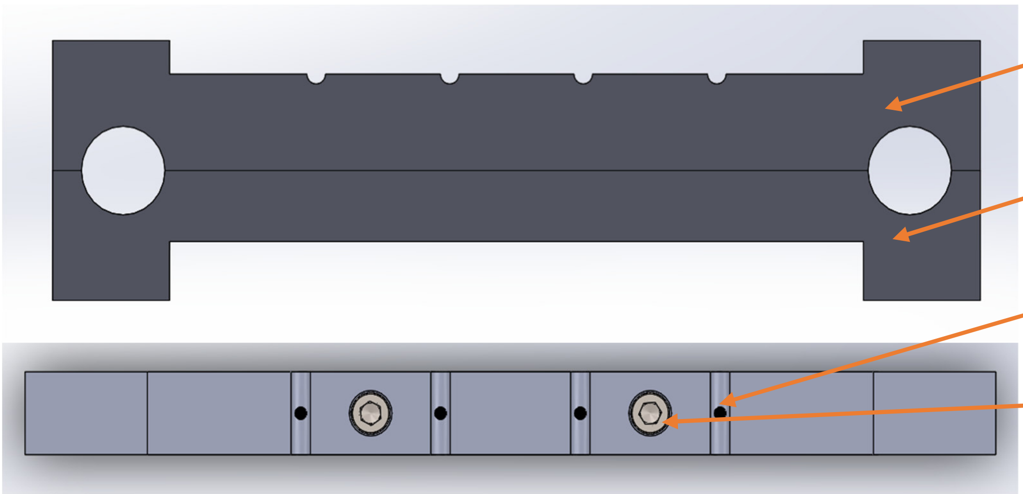


Figure 68: Support holders for both jigs.

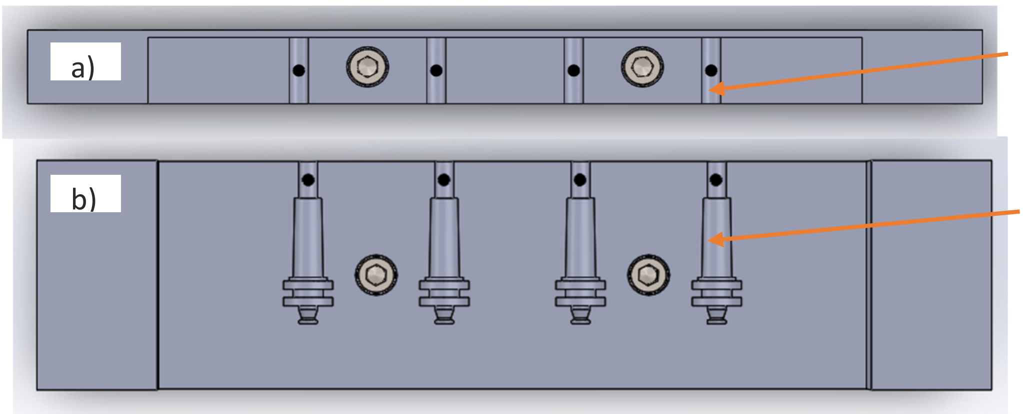


Figure 69: End of conduits holder for first (a) and second injection (b).

The gripper system was the next in line to be developed. After weighing all possible solutions, it is possible to see the final solution in Figure 70. The most important factor for a successful design is an easy and quick setup. This is accomplished by using the scale for adjusting the height and also scale marks on the sides. The design also considered rotation of the parts due to the use of two bolts or an inclination that prevents rotation.

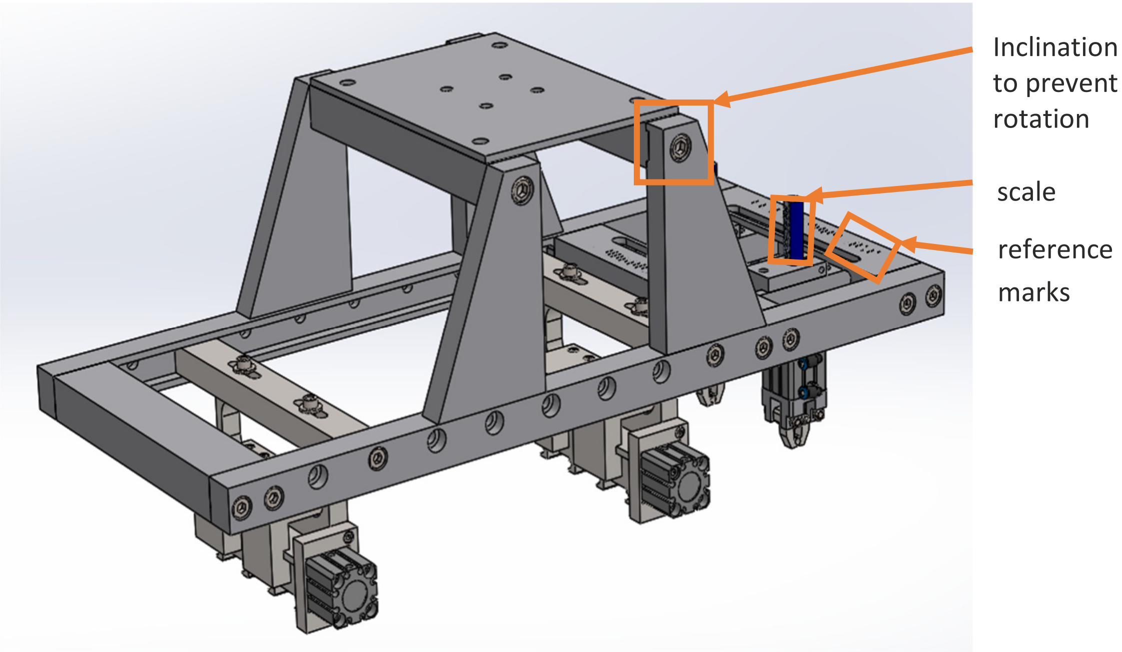


Figure 70: Final concept of the gripping system.

The scrap grippers used in the system are based on a basic linear cylinder. A part is assembled on the cylinder, which follows its linear movement and is pushing against the top of the two grippers (Figure 71). Thus, when the cylinder is acting, the gripper is opening. Thus, when the cylinder is retracting, the gripper is closing. This is a real robust system as the linear cylinder only needs a small stroke and it is far more robust than the Festo’s DHPS clamping grippers earlier described. The cylinder selection was performed following the guide in the SMC catalogue (Figure 72) and the chosen cylinders summary can be seen in Table 8.

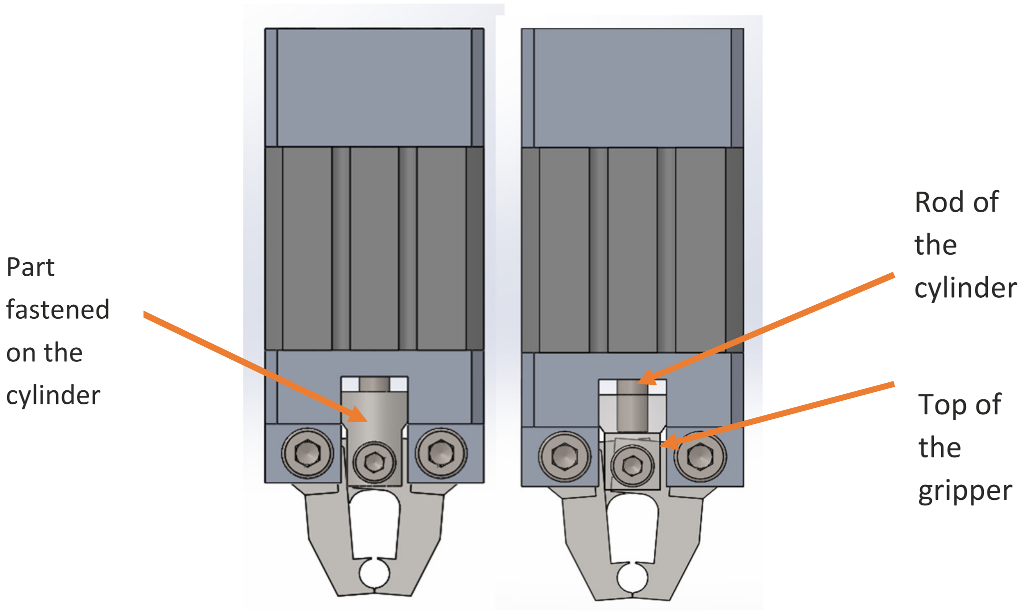


Figure 71: Gripper based on the CDQS-series cylinder.

Table 8: Ordering code for the CDQS compact cylinder for the scrap gripper.

CDQSB20-5D	
C	
D	With auto switch (built-in magnet)
Q	
S	
B	Mounting style (Through-hole/Both ends tapped common - Standard)
20	20 mm Bore size
5	5 mm stroke
D	Double acting

The cylinders used for gripping the conduits are also from the same CDQS-series. The difference is that a male thread at the end of the cylinder to screw them into the locking gripper is being used in this work. The ordering data is summarised in Table 9.

Table 9: Ordering code for the CDQS compact cylinder for the conduit gripper.

CDQSB20-5DM	
C	
D	With auto switch built-in magnet
Q	
S	
B	Mounting style (Through-hole/Both ends tapped common - (Standard)
20	20 mm Bore size
5	5 mm stroke
D	Double acting
M	Rod end male thread

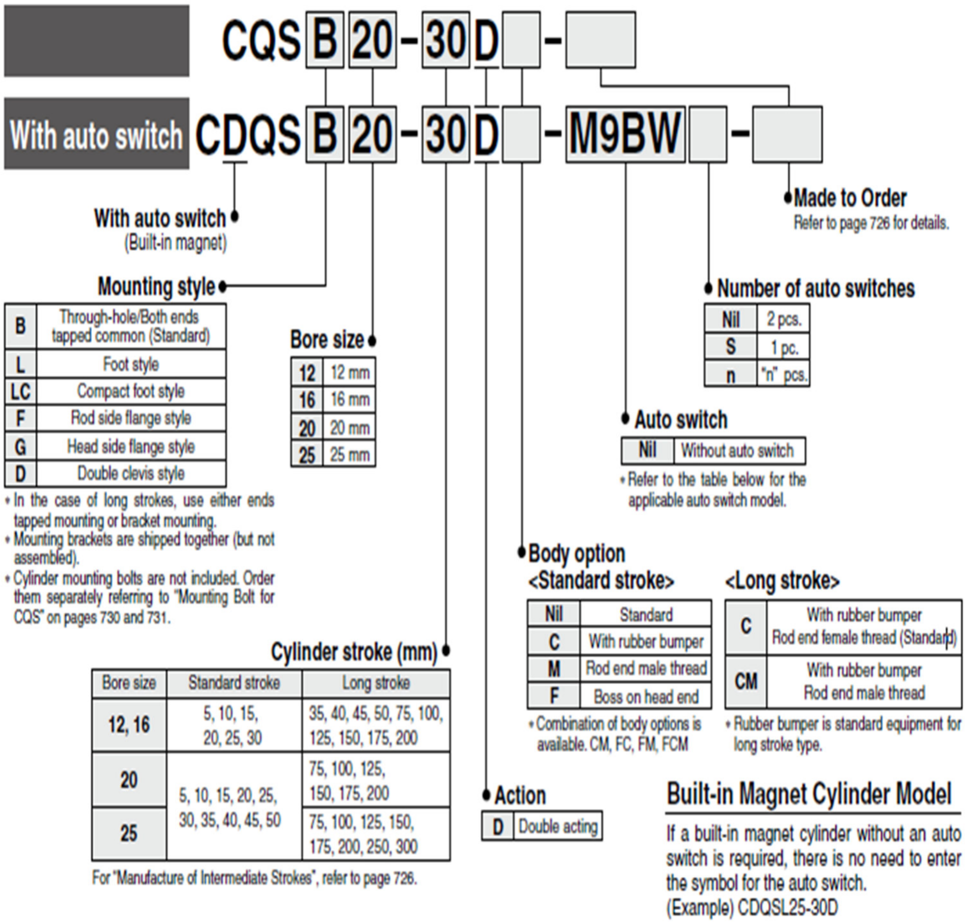
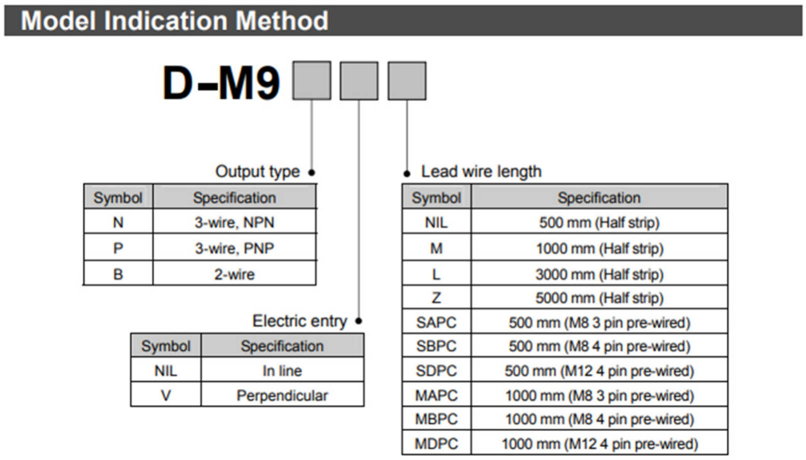


Figure 72: Screenshot out the SMC catalogue concerning the compact cylinder [30].

To detect the position of the cylinders, sensors need to be mounted on the cylinders. There are a lot of possible sensors able to be used on the CDQS-series. The sensor is chosen by looking in an SMC catalogue again (Figure 73). It was found that D-M9-series perfectly fit the needs, as the mounting is direct and easy. A description of the chosen sensor can be seen in Table 10.

Table 10: Ordering code for the D-M9 sensor family.

D-M9PSAPC-595	
D-M9	Series of the chosen sensor
P	3-wire, PNP
SAPC	500 mm (M8 3 pin pre-wired)



Model Indication Method

D-M9 □□□

Output type

Symbol	Specification
N	3-wire, NPN
P	3-wire, PNP
B	2-wire

Electric entry

Symbol	Specification
NIL	In line
V	Perpendicular

Lead wire length

Symbol	Specification
NIL	500 mm (Half strip)
M	1000 mm (Half strip)
L	3000 mm (Half strip)
Z	5000 mm (Half strip)
SAPC	500 mm (M8 3 pin pre-wired)
SBPC	500 mm (M8 4 pin pre-wired)
SDPC	500 mm (M12 4 pin pre-wired)
MAPC	1000 mm (M8 3 pin pre-wired)
MBPC	1000 mm (M8 4 pin pre-wired)
MDPC	1000 mm (M12 4 pin pre-wired)

Figure 73 : Screenshot out the SMC catalogue concerning the sensors for the compact cylinders.

The xy-manipulations are done by the use of a basic type rodless cylinder, guiding rails, a compact cylinder and appropriate designed parts around them (Figure 74).

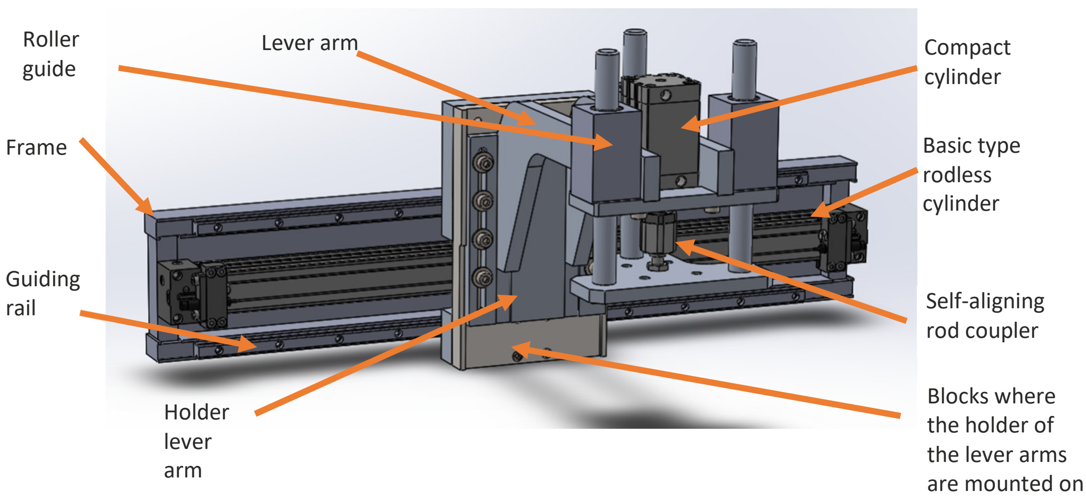


Figure 74: Final design of the XY-manipulator.

The selection process for cylinders started with the compact cylinder. The compact cylinder needs to be able to retract the total weight of the gripper system. The mass properties tool of Solidworks was used to determine the total weight of the gripper system (Figure 75). The compact cylinder needs to be able to retract approximately 10,9 kg of the gripper system.

A look into the Festo's catalogue (Figure 76) allows to see that the lowest limit would be a compact cylinder with a piston diameter of 16 mm. To make a more sustainable solution, a cylinder with a piston diameter of 40 mm was taken. The price will not be considerably more expensive, but the cylinder will have more ease in operation and increased lifetime. Thus, the theoretical retracting force at 6 bar is now 686 N and the advancing force 754 N. This is more than enough to retract the 10.9 kg (~109 N) < 686 N. The stroke that the compact cylinder needs to provide is taken at 50 mm, accompanied by a male thread where a self-aligning rod coupler

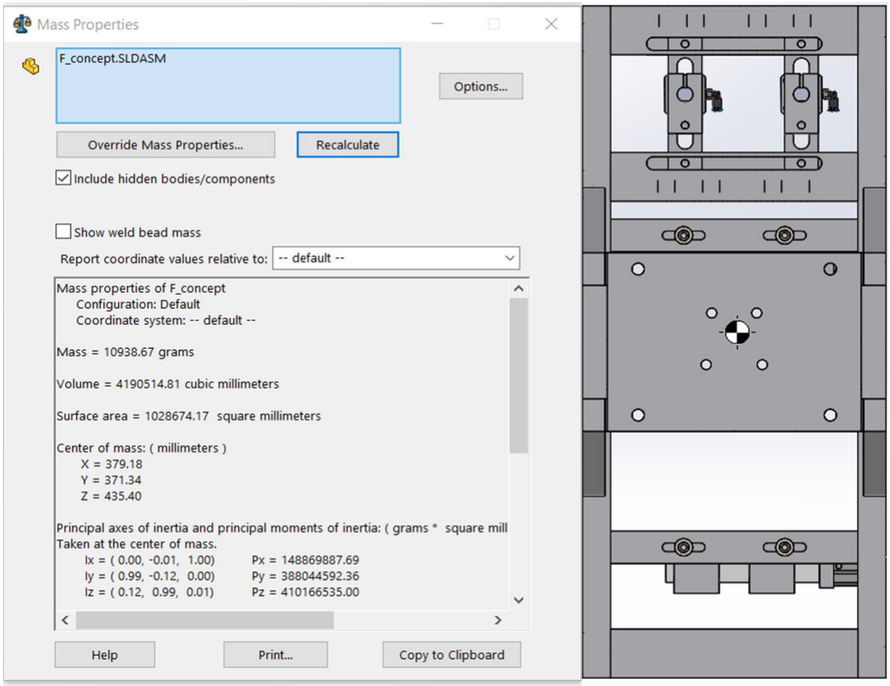
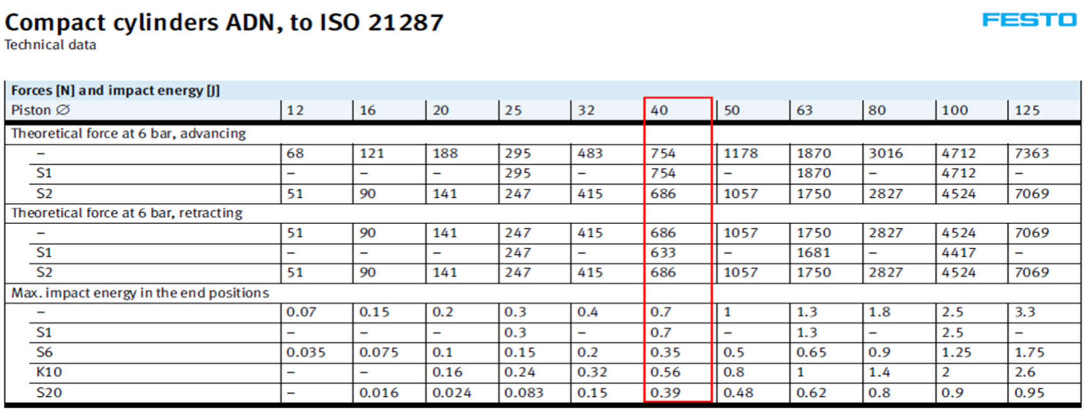


Figure 75: Mass properties of the gripper system.

is matched on to compensate angular and radial misalignment. The ordering code for the compact cylinder based on Figure 77 is defined in
Table 11.

Table 11: Ordering code for the ADN compact cylinder.

ADN-40-50-A-P-A	
ADN	Double-acting compact cylinder
40	Piston diameter in mm
50	Stroke in mm
A	Male thread
P	Flexible cushioning rings/pads at both ends
A	Position sensing via proximity sensor

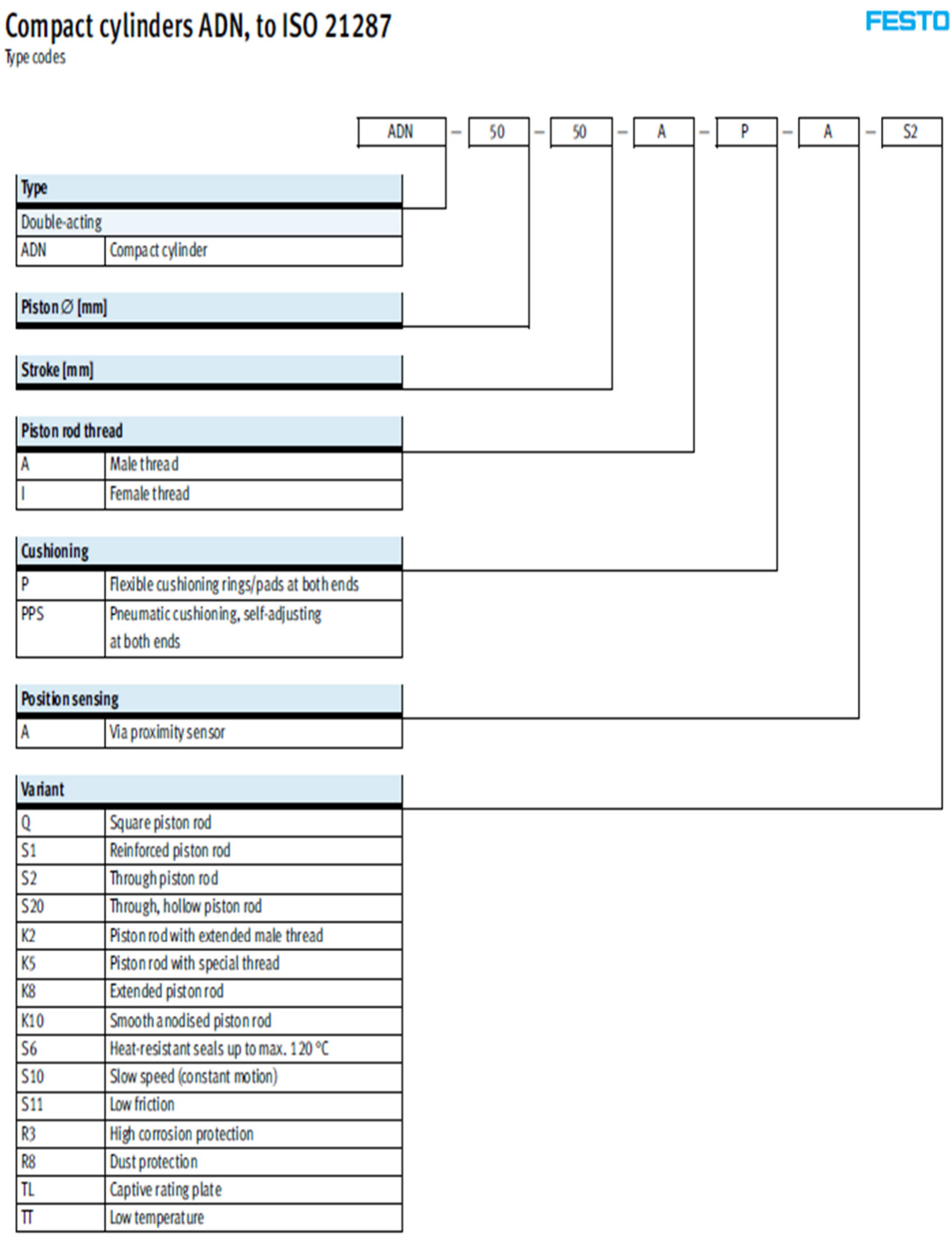


Compact cylinders ADN, to ISO 21287
Technical data

FESTO

Forces [N] and impact energy [J]											
Piston ∅	12	16	20	25	32	40	50	63	80	100	125
Theoretical force at 6 bar, advancing											
–	68	121	188	295	483	754	1178	1870	3016	4712	7363
S1	–	–	–	295	–	754	–	1870	–	4712	–
S2	51	90	141	247	415	686	1057	1750	2827	4524	7069
Theoretical force at 6 bar, retracting											
–	51	90	141	247	415	686	1057	1750	2827	4524	7069
S1	–	–	–	247	–	633	–	1681	–	4417	–
S2	51	90	141	247	415	686	1057	1750	2827	4524	7069
Max. impact energy in the end positions											
–	0.07	0.15	0.2	0.3	0.4	0.7	1	1.3	1.8	2.5	3.3
S1	–	–	–	0.3	–	0.7	–	1.3	–	2.5	–
S6	0.035	0.075	0.1	0.15	0.2	0.35	0.5	0.65	0.9	1.25	1.75
K10	–	–	0.16	0.24	0.32	0.56	0.8	1	1.4	2	2.6
S20	–	0.016	0.024	0.083	0.15	0.39	0.48	0.62	0.8	0.9	0.95

Figure 76: Theoretical forces for compact cylinders ADN [34].



Compact cylinders ADN, to ISO 21287 FESTO

Type codes

ADN – 50 – 50 – A – P – A – S2

Type	
Double-acting	
ADN	Compact cylinder

Piston ∅ [mm]

Stroke [mm]

Piston rod thread	
A	Male thread
I	Female thread

Cushioning	
P	Flexible cushioning rings/pads at both ends
PPS	Pneumatic cushioning, self-adjusting at both ends

Position sensing	
A	Via proximity sensor

Variant	
Q	Square piston rod
S1	Reinforced piston rod
S2	Through piston rod
S20	Through, hollow piston rod
K2	Piston rod with extended male thread
K5	Piston rod with special thread
K8	Extended piston rod
K10	Smooth anodised piston rod
S6	Heat-resistant seals up to max. 120 °C
S10	Slow speed (constant motion)
S11	Low friction
R3	High corrosion protection
R8	Dust protection
TL	Captive rating plate
TT	Low temperature

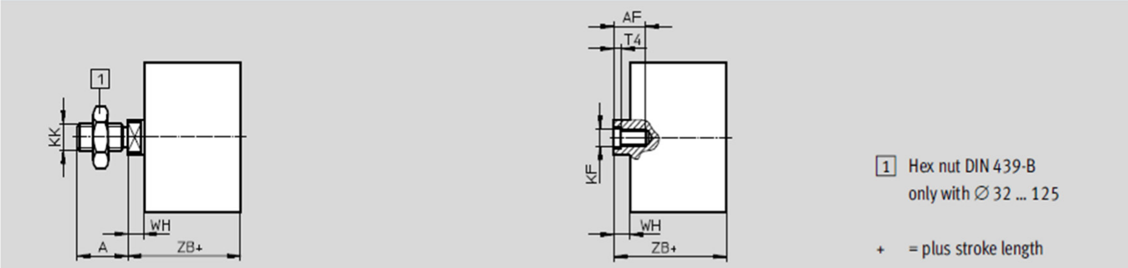
Figure 77: Ordering code information for compact cylinders ADN [34].

The ordering code for the self-aligning rod coupler can be determined out of the datasheet from the ADN-compact cylinder (Figure 78) and the datasheet from the self-aligning rod coupler (Figure 79). It is possible to see that the thread (KK) is M10x1.25. This is all the information needed to determine the self-aligning rod coupler.

Compact cylinders ADN, to ISO 21287
Technical data

FESTO

Dimensions – Variants Download CAD data ➔ **www.festo.com**
Basic version



∅ [mm]	A −0.5	A1	A2	AF min.	AF5 min.	B ∅	D7 ∅	D8	D9 ∅	L5	KF	KF5	KK
12	10	1 ... 10	1 ... 300	8	–	–	–		–	–	M3	–	M5
16	12			10			4.5		3.2	3	M4		M6
20	16			14	12	18	6		3.8	2	M6	M5	M8
25													
32	19	1 ... 20	1 ... 400	16	14	27	8		4.5	3	M8	M6	M10x1.25
40													
50	22			20	16	31	10		6	3.5	M10	M8	M12x1.25
63													
80	28	1 ... 30	1 ... 500		20	35	–	G1/8	8	–	M12	M10	M16x1.5
100													
125	40	1 ... 40		25	–	–		G1/4	11.7		M16	–	M20x1.5

Figure 78: Datasheet screenshot for the ADN-cylinder with dimensions.

Order code Part No.	Type	for piston rod thread KK	Material	Weight kg	max. permissible tensile and compressive load N (≈ kp)	Radial misalignment P mm
6528	FK-M 4	M 4	Galvanized steel	0.015	750 (75)	0.5
30984	FK-M 5	M 5		0.020	1200 (120)	0.5
2061	FK-M 6	M 6		0.017	1200 (120)	0.5
2062	FK-M 8	M 8		0.050	2500 (250)	0.5
2063	FK-M 10	M 10		0.210	5000 (500)	0.7
6140	FK-M 10 x 1.25	M 10 x 1.25		0.210	5000 (500)	0.7
2064	FK-M 12	M 12		0.210	5000 (500)	0.7
6141	FK-M 12 x 1.25	M 12 x 1.25		0.215	5000 (500)	0.7
2065	FK-M 16	M 16		0.670	10000 (1000)	1
6142	FK-M 16 x 1.5	M 16 x 1.5		0.650	10000 (1000)	1
2066	FK-M 20	M 20		0.700	10000 (1000)	1
6143	FK-M 20 x 1.5	M 20 x 1.5		0.720	10000 (1000)	1
4029	FK-M 24	M 24 x 2		1.670	24000 (2400)	1
10485	FK-M 27 x 2	M 27 x 2		2.100	30000 (3000)	1
10746	FK-M 36 x 2	M 36 x 2		5.800	40000 (4000)	1

Figure 79: Datasheet screenshot from the self-alligning rod coupler.

After taking this decision, guiding rails are chosen based on the moment that they will initiate at the frame. Therefore, Solidworks® mass properties is used to calculate the total weight of the gripper system accompanied by the lever arms, the holder of the lever arms and the blocks where the holder of the lever arms is mounted on (Figure 80).

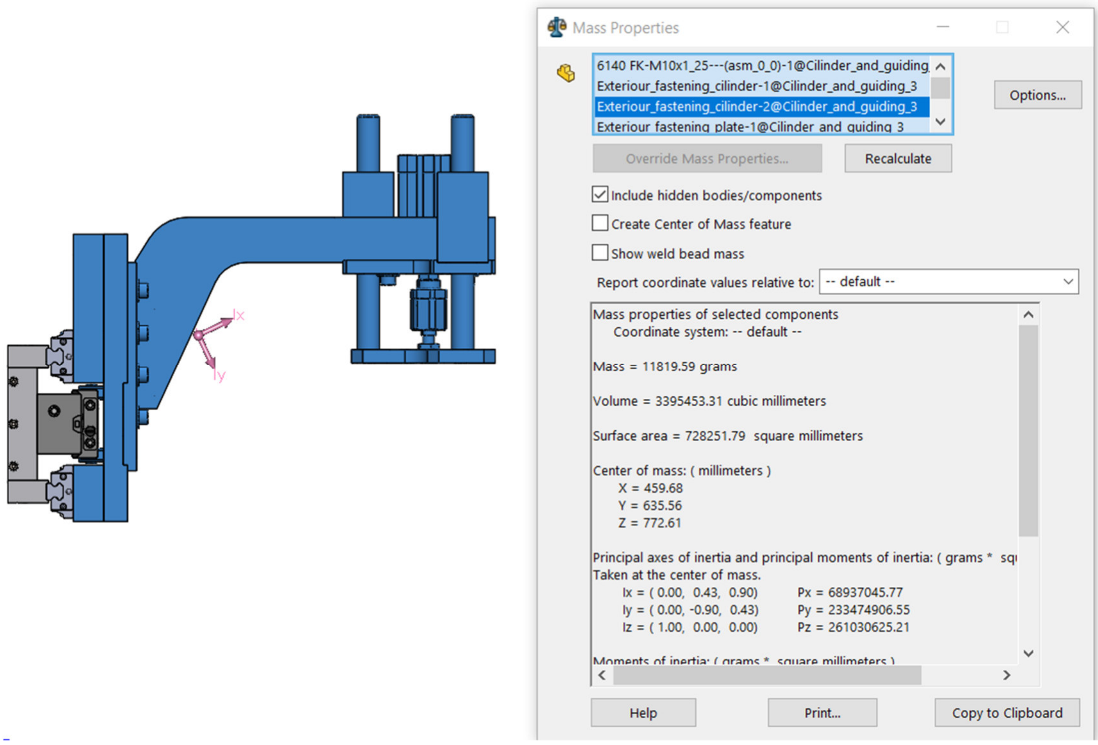


Figure 80: Mass properties of the lever system.

It is possible to conclude that the complete lever system will be around 12 kg. The sum of the gripping system weight with this will totalize (10,9+12) 22,9 kg, which will cause a bending moment. After checking the center of mass of this assembly, it is possible to see that the bending arm will be around 192 mm (Figure 81). Thus, making a quick calculation of the caused bending moment: M= 22,9 x 10 x 0,192 = 44 N·m. Thus, it will be needed to select guiding rails that can withstand this moment.

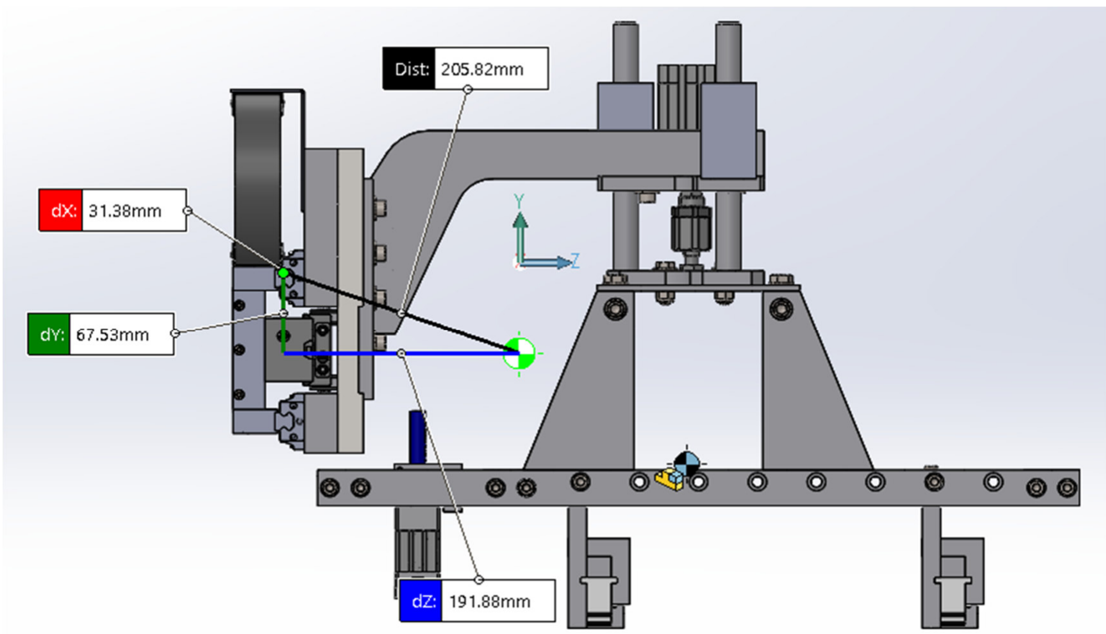
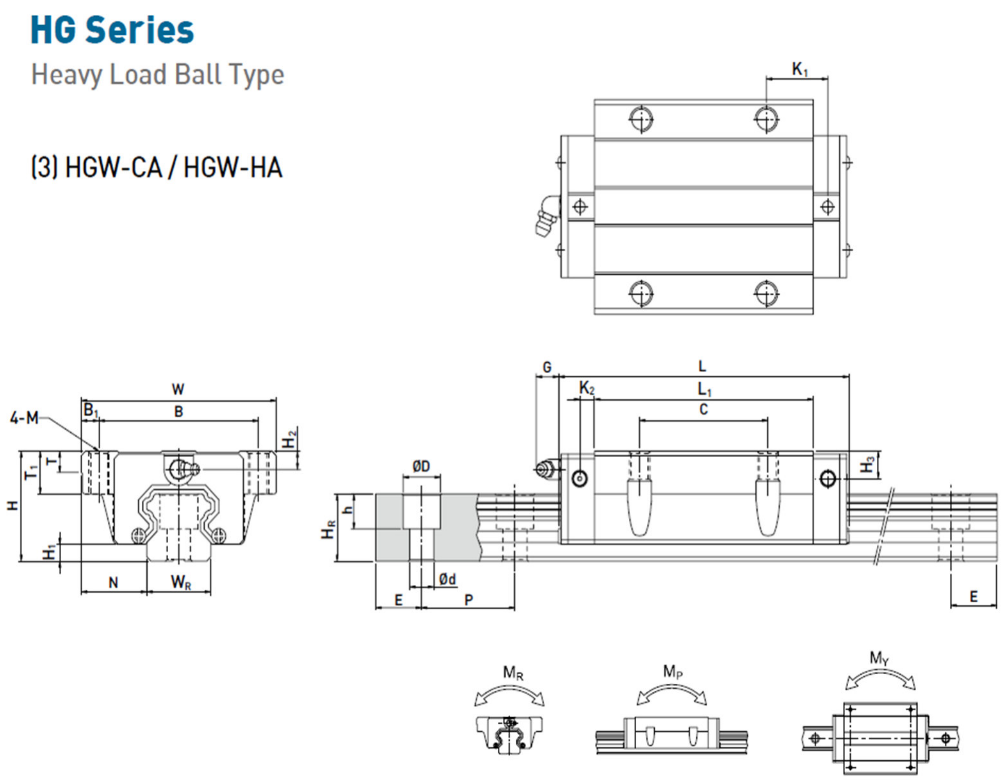


Figure 81: Arm of the caused moment of the total mass of the lever system and gripping system.

Looking in the catalog of linear guideways from HiWin® (Figure 82), it is possible to see that the moment that is important for this work is M_R. In our case, the moment is 44 Nm, thus, the HGW15CA linear guide can resist a static rated moment of 120 Nm, which is more than sufficient. To have smooth guidance, one above and under the basic type rodless cylinder have been placed.



Model No.	Dimensions of Assembly (mm)			Dimensions of Block (mm)														Dimensions of Rail (mm)							Mounting Bolt for Rail	Basic Dynamic Load Rating	Basic Static Load Rating	Static Rated Moment			Weight	
	H	H_1	N	W	B	B_1	C	L_1	L	K_1	K_2	G	M	T	T_1	H_2	H_3	W_R	H_R	D	h	d	P	E	(mm)	C(kN)	C_0(kN)	M_R kN-m	M_P kN-m	M_Y kN-m	Block kg	Rail kg/m
HGW15CA	24	4.3	16	47	38	4.5	30	39.4	61.4	8	4.85	5.3	M5	6	8.9	3.95	3.7	15	15	7.5	5.3	4.5	60	20	M4x16	14.7	23.47	0.12	0.10	0.10	0.17	1.45

Figure 82: Linear guide selection based on the bending moment [35].

Last, the rodless cylinder needs to be selected, as the bending moment is supported by the guiding rails (Figure 83). It is necessary to check if the force supplied by the rodless cylinder is going to be sufficient to move the weight of the gripper system and the lever system.

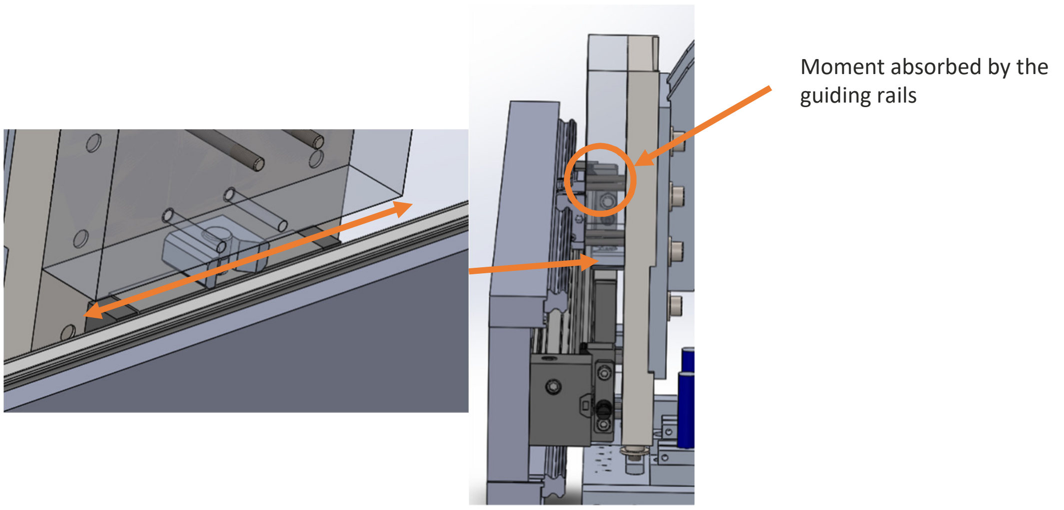


Figure 83: Rodless cylinder connection to the lever system

The catalogue shows that a cylinder with bore size 25 mm has a theoretical output of 294 N. This is sufficient to move the lever and the gripper systems (see Figure 84).

Theoretical Output

(N)

Bore size (mm)	Piston area (mm^2)	Operating pressure (MPa)						
		0.2	0.3	0.4	0.5	0.6	0.7	0.8
10	78	15	23	31	39	46	54	62
16	200	40	60	80	100	120	140	160
20	314	62	94	125	157	188	219	251
25	490	98	147	196	245	294	343	392
32	804	161	241	322	402	483	563	643
40	1256	251	377	502	628	754	879	1005
50	1962	392	588	784	981	1177	1373	1569
63	3115	623	934	1246	1557	1869	2180	2492
80	5024	1004	1507	2009	2512	3014	3516	4019
100	7850	1570	2355	3140	3925	4710	5495	6280

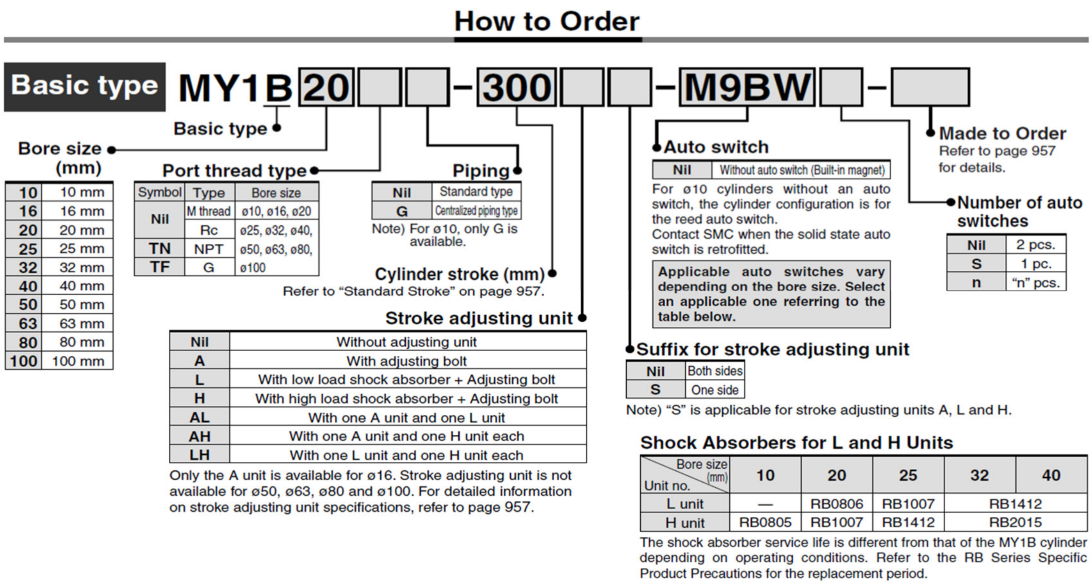
Note) Theoretical output (N) = Pressure (MPa) x Piston area (mm^2)

Figure 84: Theoretical output of the rodless cylinder

The order code following the guidelines in the datasheet (Figure 85) brings us to the selection seen in Table 12.

Table 12: Ordering code for the basic rodless cylinder.

MY1B25-500AZ	
MY1	
B	Basic type
25	Bore size in mm
500	Cylinder stroke in mm
AZ	Stroke adjusting unit



How to Order

Basic type MY1B 20 □ □ - 300 □ □ - M9BW □ - □

Basic type

Bore size (mm)

10	10 mm
16	16 mm
20	20 mm
25	25 mm
32	32 mm
40	40 mm
50	50 mm
63	63 mm
80	80 mm
100	100 mm

Port thread type

Symbol	Type	Bore size
Nil	M thread	ø10, ø16, ø20
	Rc	ø25, ø32, ø40,
TN	NPT	ø50, ø63, ø80,
TF	G	ø100

Piping

Nil	Standard type
G	Centralized piping type

Note) For ø10, only G is available.

Cylinder stroke (mm)
Refer to "Standard Stroke" on page 957.

Stroke adjusting unit

Nil	Without adjusting unit
A	With adjusting bolt
L	With low load shock absorber + Adjusting bolt
H	With high load shock absorber + Adjusting bolt
AL	With one A unit and one L unit
AH	With one A unit and one H unit each
LH	With one L unit and one H unit each

Only the A unit is available for ø16. Stroke adjusting unit is not available for ø50, ø63, ø80 and ø100. For detailed information on stroke adjusting unit specifications, refer to page 957.

Auto switch

Nil	Without auto switch (Built-in magnet)

For ø10 cylinders without an auto switch, the cylinder configuration is for the reed auto switch.
Contact SMC when the solid state auto switch is retrofitted.

Applicable auto switches vary depending on the bore size. Select an applicable one referring to the table below.

Made to Order
Refer to page 957 for details.

Number of auto switches

Nil	2 pcs.
S	1 pc.
n	"n" pcs.

Suffix for stroke adjusting unit

Nil	Both sides
S	One side

Note) "S" is applicable for stroke adjusting units A, L and H.

Shock Absorbers for L and H Units

Unit no. \ Bore size (mm)	10	20	25	32	40
L unit	—	RB0806	RB1007	RB1412	
H unit	RB0805	RB1007	RB1412	RB2015	

The shock absorber service life is different from that of the MY1B cylinder depending on operating conditions. Refer to the RB Series Specific Product Precautions for the replacement period.

Figure 85: Ordering code for the rodless cylinder [30]

Another important factor of the design is that the blocks have been split up into three parts. The reason behind this is some problems in the past with threads getting damaged. Thus, one part is in steel while the other two parts are in aluminium (Figure 86).

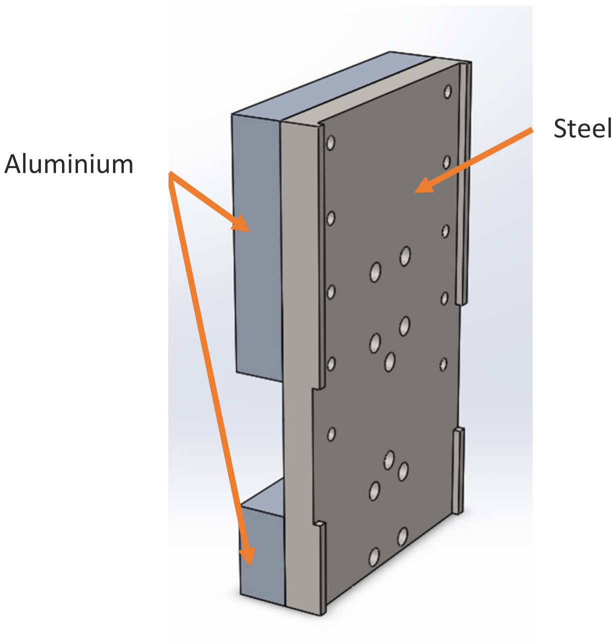


Figure 86: Blocks where the lever system is mounted on.

The steel structure fastened on the Babyplast® injection machines is designed around the above-described parts (Figure 87). The fastening to the Babyplast® is realised by welding a plate at the end of the steel structure and fastening it with bolts on to the Babyplast®. A plate is welded on the feet of the steel structure with thread inside. The plastic height-adjustable feet are inserted to eliminate bumps in the floor and create a solid structure. The plastic also absorbs vibrations.

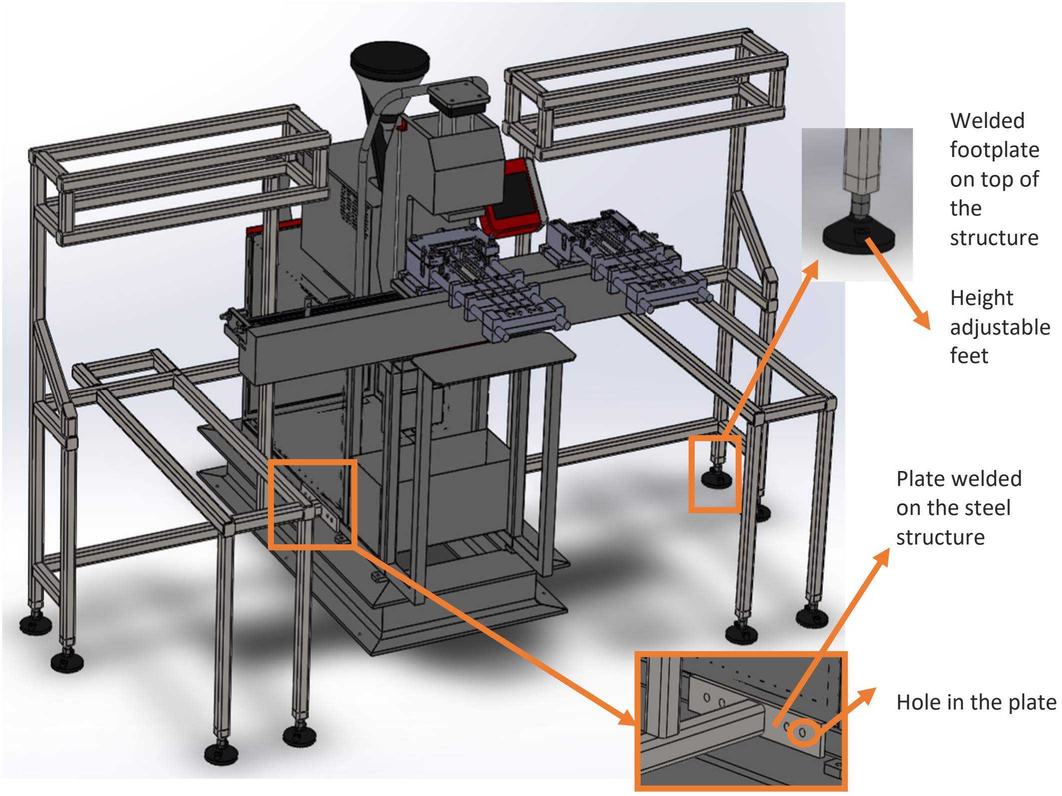


Figure 87: Babyplast with the steel frame.

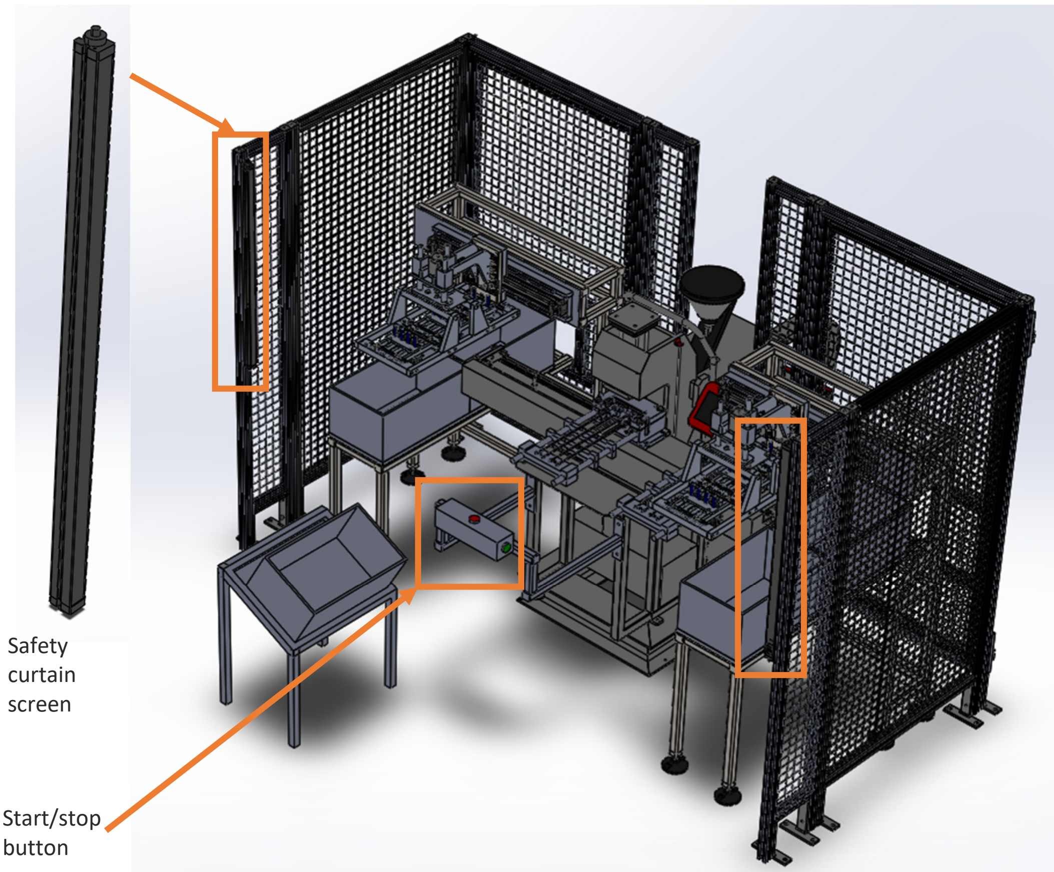


Figure 88: Front view of the safety structure.

4.2.5 Safety and environmental concerns

The most important safety concerns are those related to the operators. Using a manipulator is going hand in hand with moving parts at a height where the operator can get hurt when there is not an appropriate safety design.

The safety system designed around the conduit manipulator consists of safety fences, safety curtain and safety hinges. The lighting screens prevent the operator to walk in, as soon as the start button is pushed (Figure 88). When the operator is walking in after pushing the start button, all movements need to be stopped to provide safety. Holes were provided in the back of the safety fences to take out the filled scrap boxes. These holes are foreseen in the doors that are equipped with safety hinges (Figure 89).

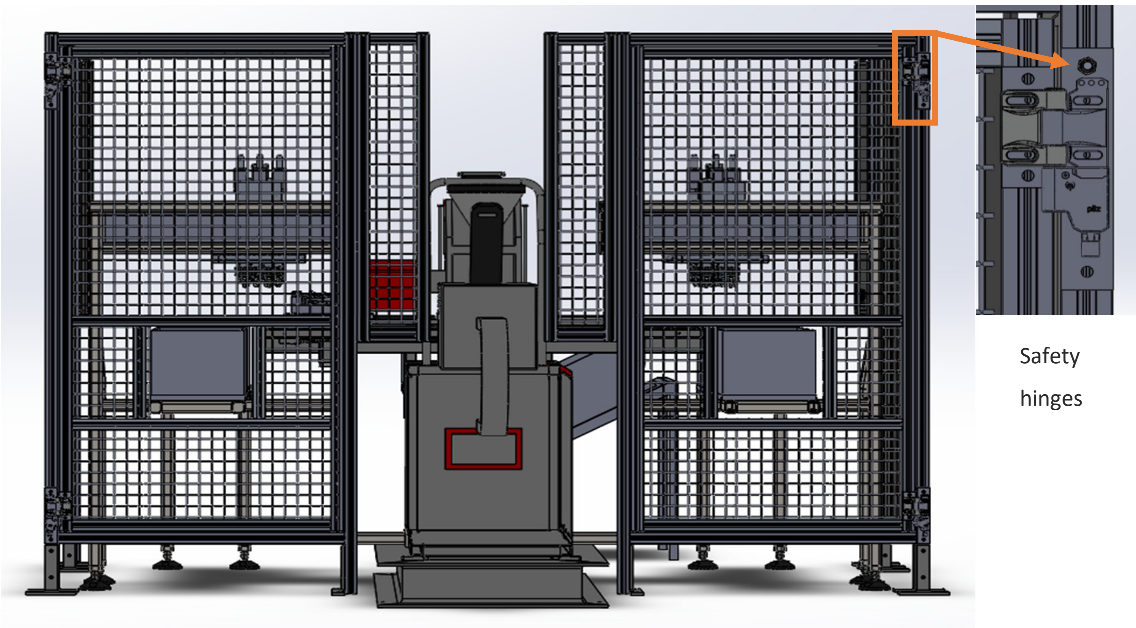


Figure 89: Back view of the safety structure.

4.3 Mechanical design

4.3.1 Components' design

The components that need to be designed can be identified by taking a closer look at the different sub-assemblies.

Gripper system

The designed parts for the gripper system (Figure 90) that need to be manufactured can be found in Table 13.

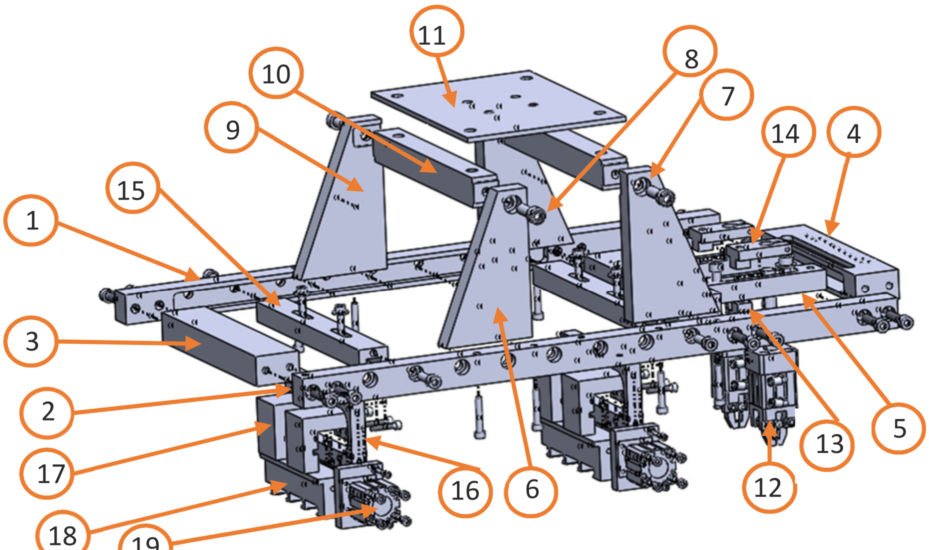
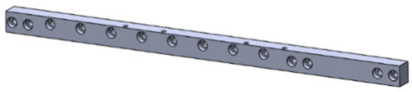
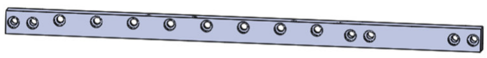
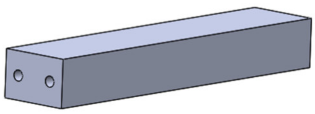
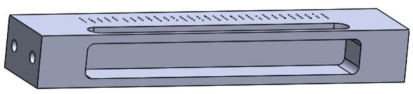
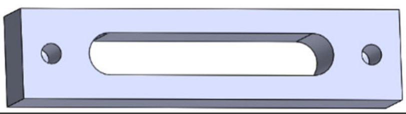
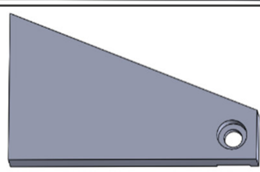
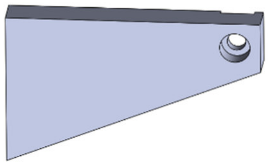
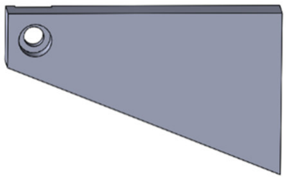
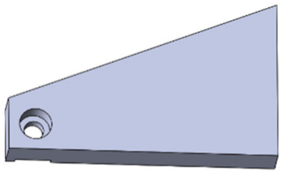
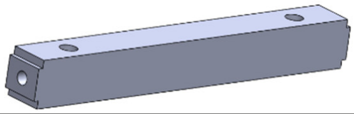
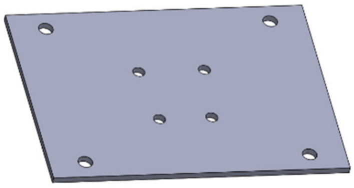
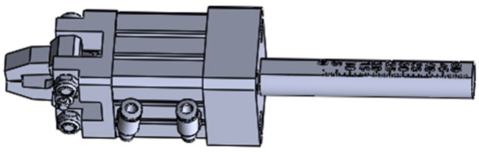
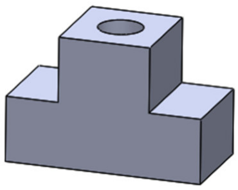
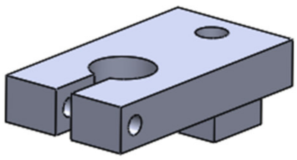
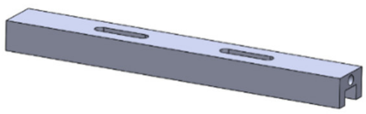
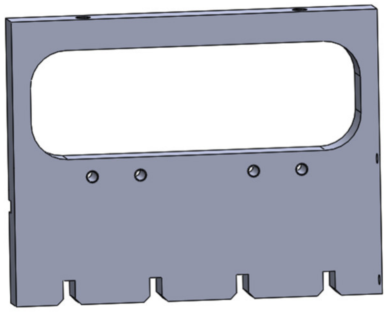
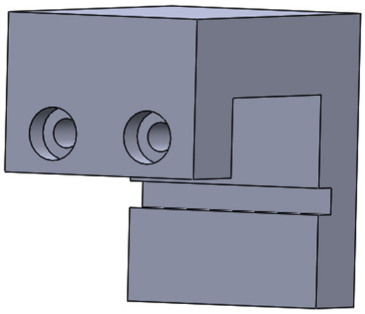
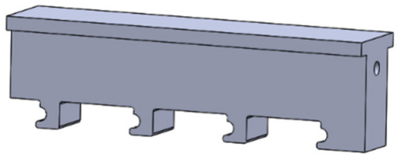
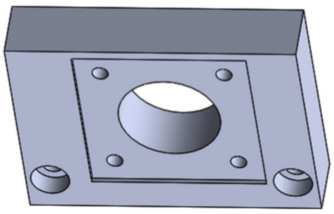


Figure 90: Exploded view gripper system.

Table 13: Designed parts considering the gripper system.

Nr.	Description	QTY	Picture
1	Longer_side_1	1	
2	Longer_side_2	1	
3	Short_side_gripping_system	1	
4	Side_holder_scrap_gripper	2	
5	Middle_holder_scrap_gripper	2	
6	Vertical_side_1_gripping_system	1	

Nr.	Description	QTY	Picture
7	Vertical_side_2_gripping_sys tem	1	
8	Vertical_side_3_gripping_sys tem	1	
9	Vertical_side_4_gripping_sys tem	1	
10	Span_long_sides_gripper	2	
11	Mounting_plate_gripper	1	
12	Scrap gripper	2	
13	Lock_down_gripper	2	
14	Lock_up_gripper	2	
15	Middle_support_holder_for_ gripper	2	

Nr.	Description	QTY	Picture
16	Fixed_distance_plate	2	
17	L_guidance_lock_gripper	4	
18	Locking_gripper	2	
19	Cylinder_mounting_block_lo ck_gripper	2	

The above described quantities are for one gripper system. For the whole project, we need two gripper systems. One left of the injection machine and one in the right.

Scrap gripper

The designed parts for the scrap gripper (Figure 91) that need to be manufactured can be found in Table 14.

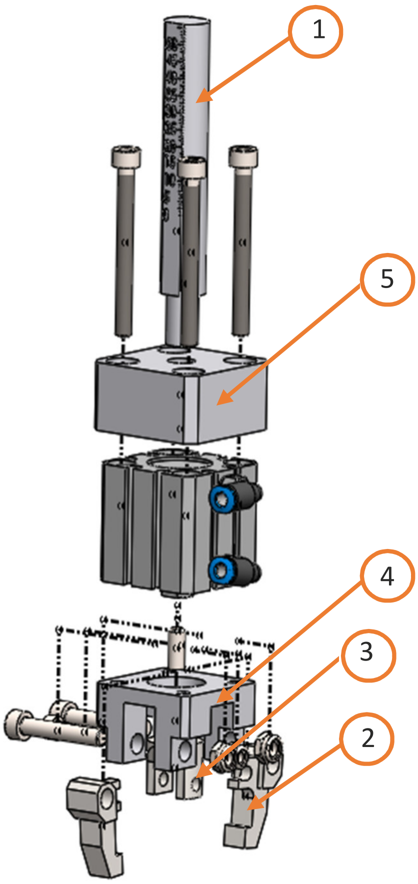
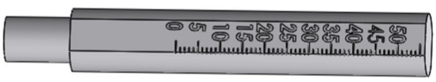
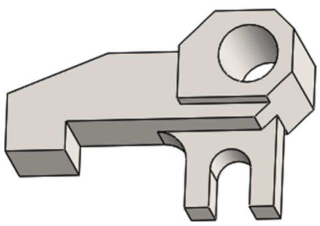
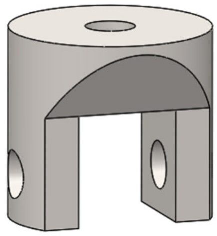
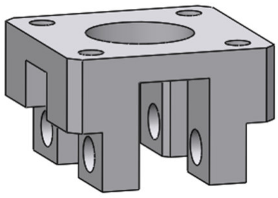
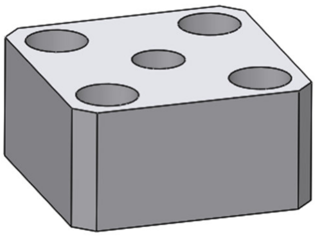


Figure 91: Exploded view of the scrap gripper.

Table 14: Designed parts considering the scrap gripper.

Nr.	Description	QTY	Picture
1	Height adjusting	1	
2	Gripper	2	

Nr.	Description	QTY	Picture
3	Extension_on_cylinder	1	
4	Bottom_scrap_gripper	1	
5	Top_scrap_gripper	1	

The above described quantities are for one scrap gripper. In one gripper system, there are two scrap grippers used. In the whole project comes this to a total of four scrap grippers.

Lever system

The designed parts for the lever system (Figure 92) that need to be manufactured, can be found in Table 15.

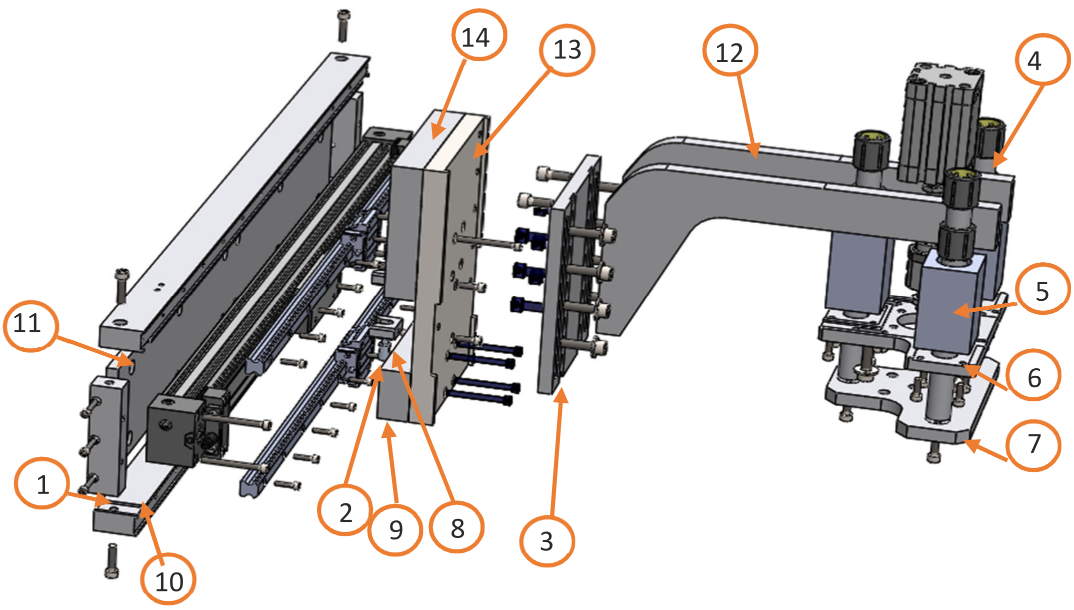
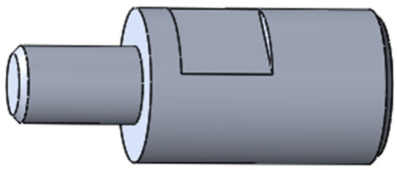
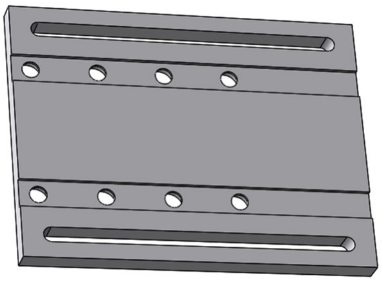
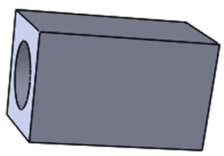
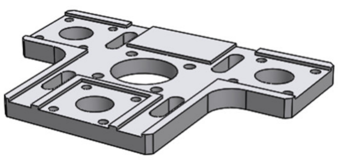
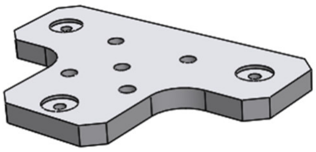
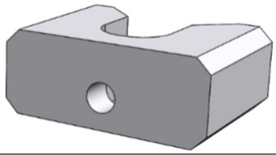
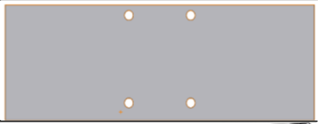
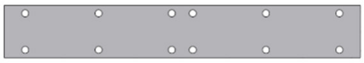
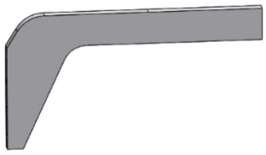
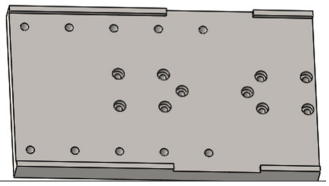
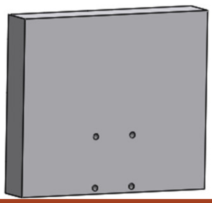


Figure 92: Exploded view of the lever sytem.

Table 15: Designed parts considering the lever system.

Nr.	Description	QTY	Picture
1	Vertical_support_holder_guiding_rail	2	
2	Rod_for_block_linear_guide	2	
3	Fixing_plate_lever_arm	1	
4	Guiding_cylinder	3	
5	Bearing_housing	3	
6	Guide_and_mounting_plate_lever_system_highest	1	

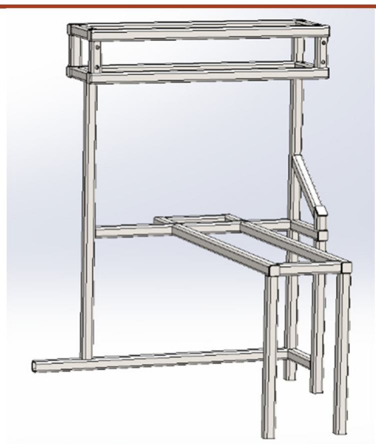
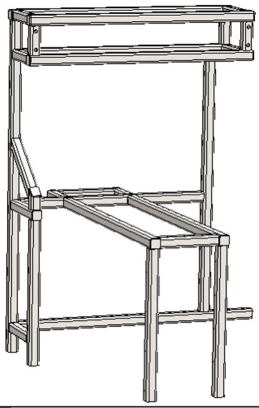
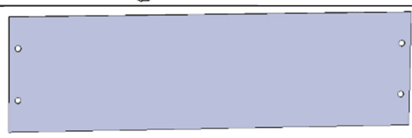
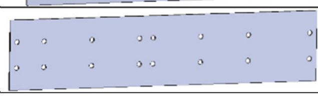
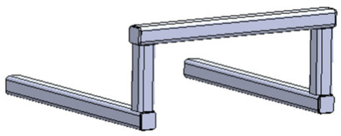
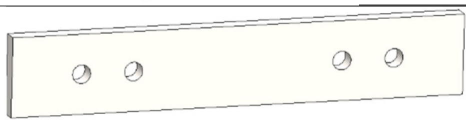
Nr.	Description	QTY	Picture
7	Guide_and_mounting_plate_lever_system_lowest	1	
8	Guiding_block_for_linear_guide	2	
9	Alu_block_2_lever_arm	1	
10	Holder_guiding_rail_cylinder	2	
11	Backplate_mounting_linear_guide	1	
12	Lever_arm	2	
13	St_block_holder_lever _arm	1	
14	Al_Blok1_lever_holder	1	

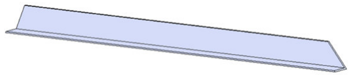
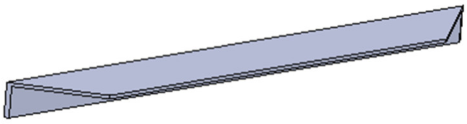
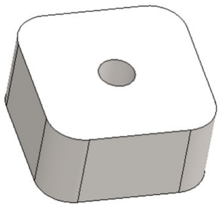
The above described quantities are for one lever system. The whole project consists of two lever systems.

Frame

The designed parts for the frame around the injection machine that need to be manufactured can be found in Table 16.

Table 16: Designed parts considering the frame.

Description	QTY	Picture
Frame_right	1	
Frame_left	1	
Top_plate_frame	2	
Bottom_plate_frame	2	
Front_plate_frame	2	
Mounting_start_button	1	
Connection_plate_steel_structure_babyplast	2	

Description	QTY	Picture
Connection_plate_start _and_babyplast	2	
L-profile-40x40x2x1005	4	
L-profile-40x40x2x305	4	
Welding_plate_for_feet	8	

The above quantities that are described are all for one complete frame.

Jigs

The designed parts for the lever system (Figure 93) that need to be manufactured can be found in Table 17.

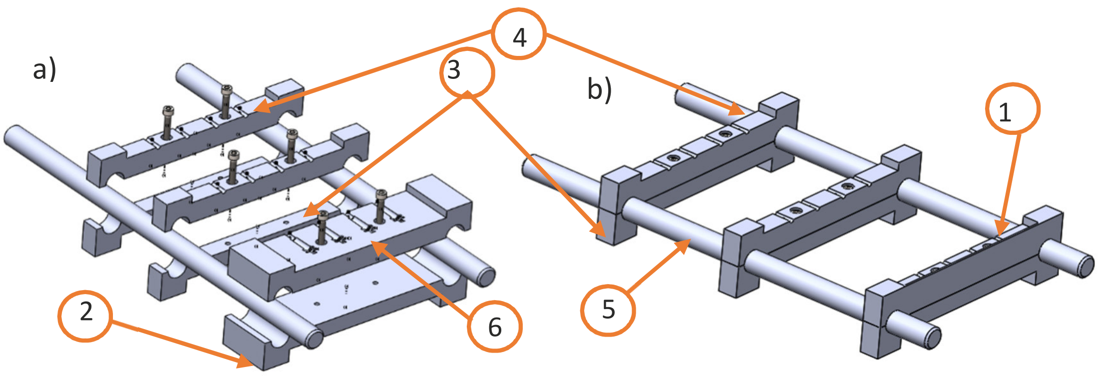
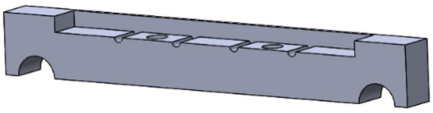
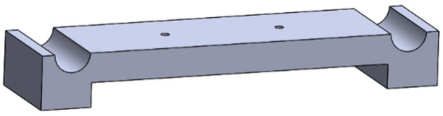
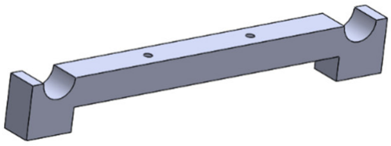
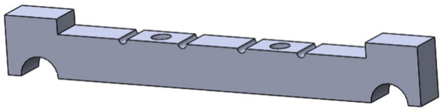
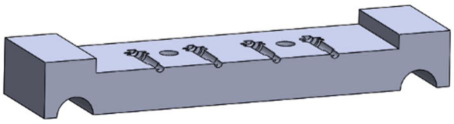


Figure 93: Jigs for the a) first injection, and b) second injection.

Table 17: Designed parts considering the jigs.

Nr.	Description	QTY	Picture
1	First_injection_top_jig	1	
2	Second_injection_botto m_ jig	1	
3	Middle_support_holder_jig_down	5	
4	Middle_support_holder_jig_up	4	
5	Cylinder_jig	4	
6	Second_injection_top_jig	1	

The described quantities in the above table are for both the jigs together.

Next, some important notes considering all the 2D-drawings are provided. All the 2D drawings are drawn in the first angle projection. The standard used for part drawings is ISO 2768-mK (Annex 7.2.1). This standard is used as a general tolerance for linear and angular dimensions. Where more precise tolerance was needed, they are mentioned specifically on the drawings. The standard tolerance used for welding assemblies is ISO 19320-AE (annex 7.2.2). Most of the parts are designed out of AW6082 (aluminium alloy), S235JR (steel) and PTFE (polymer). It was chosen to take most of the parts in AW6082 only the St_block_holder_lever_arm and the frame are in S235JR to ensure the strength, and the locking gripper in PTFE to decrease the slip. The datasheets considering these materials can be found in annex 7.6. The way of presenting the roughness and welding has been cleared out in Annex 7.2.3 and Annex 7.2.4.

4.3.2 FEM analyses of the critical parts

The finite element method is an analysis method that divides a complex mathematical problem into finite smaller problems. This method is used to predict how a design is going to react (stress, displacement,...) under certain loads or other influences. Thus, after designing, it is possible to check if the design meets the requirements. A few FEM analyses for critical components in the structure are provided. Critical factors in my design are the miss alignment of the grippers due to deflection or failure of components due to concentration of tension.

Before looking at the FEM analysis, it is worth to refer to the datasheet of AW6082. A yield point with a minimum value of 240 MPa can be found.

Lever arm (Figure 94)

The part is fixed at the holes. An external load (150 N), that is a bit more than the total weight of the system that is putting pressure on the arm is used as a reference to check the output of the analysis. As two arms will carry the load the 150 N will bi divided by 2, resulting in a load per arm of 75N.

von Mises

As previously mentioned, the yield point has a value of 240 MPa. It is possible to see that the value that occurs is only 4 MPa, which is a lot less than the yielding point, concluding that there is no problem in terms of stress here.

Displacement

To avoid misalignment, is it needed to make sure that there is not a remarkable displacement in the vertical direction. The maximal deflection is around 0.054 mm, causing no problem in the designed system.

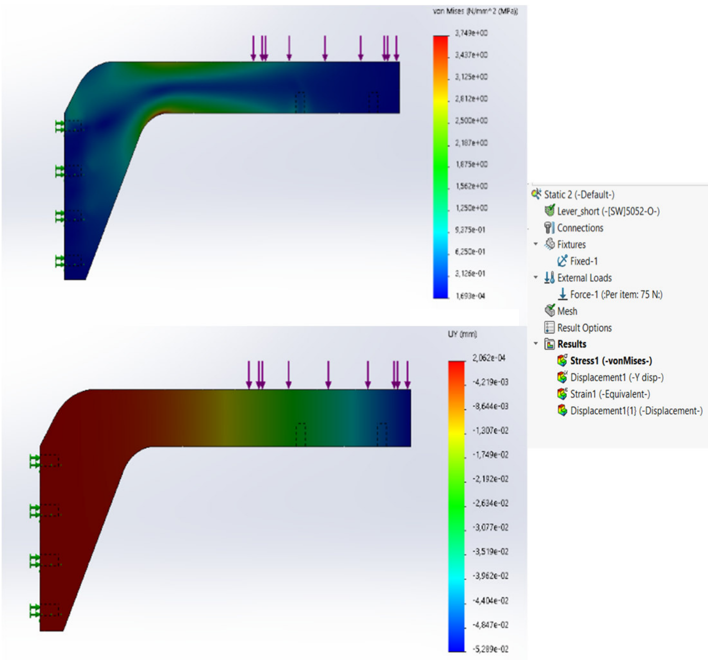


Figure 94: FEM analysis of the lever arm.

Vertical trapezium sides (Figure 95)

The part is fixed at the top. An external load (110 N), the total weight of the system that is putting pressure on the sides, is used as a reference to check the output of the analysis. As there are four vertical trapezium sides that will carry the load (110 N), the load need to be divided by 4, resulting in a load of 27.5 N on one side.

von Mises

As previously mentioned, the yield point has a value of 240 MPa. The value that occurs is smaller than 1 MPa, which is a lot less than the yielding point, concluding that there is no problem in installed stresses here.

Displacement

To avoid misalignment, we need to make sure that there is not a remarkable displacement in the vertical direction. The maximal deflection is around 0.0004458 mm, causing no problem in the designed system.

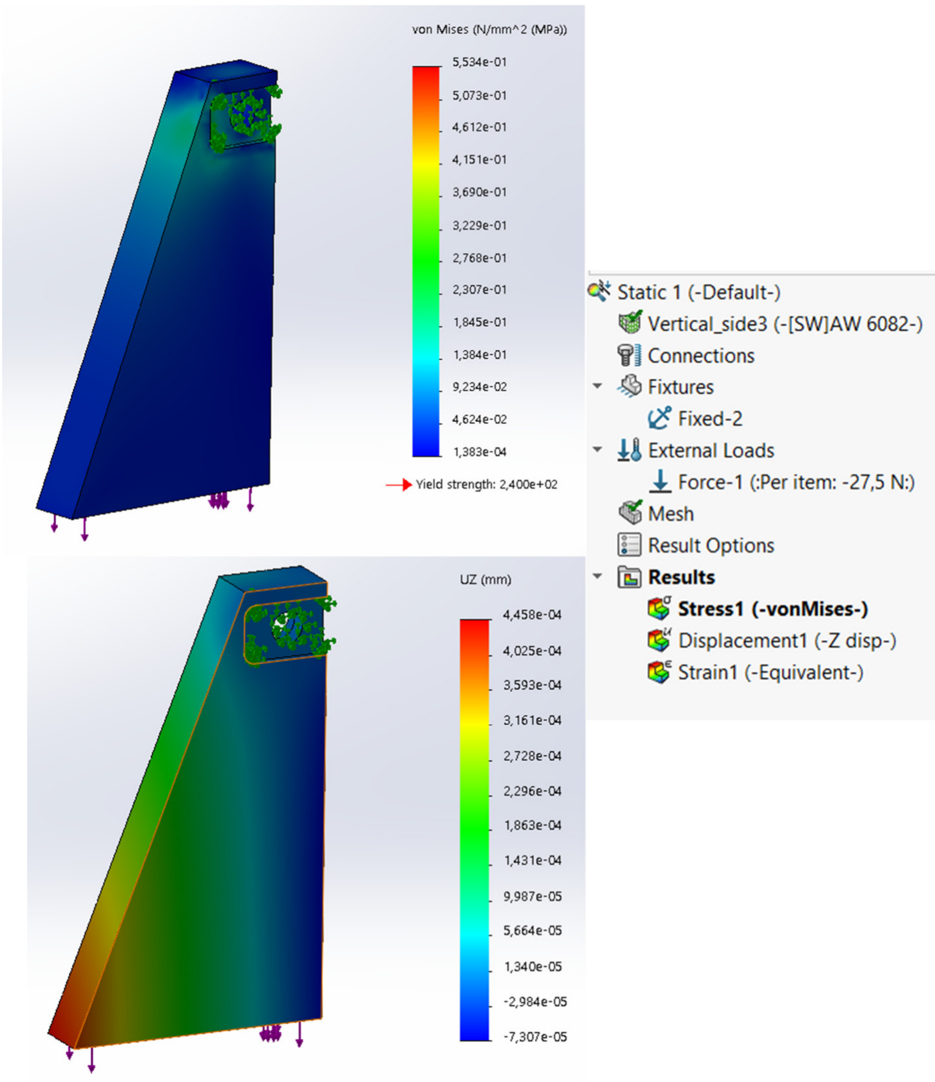


Figure 95: FEM analysis of the vertical side.

Middle support holder (Figure 96)

The part is fixed at the sides. An external load of 12 N is the total weight of the parts that is assembled under the middle support holder, which is used as a reference to check the output of the analysis.

von Mises

As previously mentioned, the yield point has a value of 240 MPa. The value that occurs is less than 1 MPa, which is a lot less than the yielding point. Concluding that there is no problem regardinf the stress here.

Displacement

To avoid misalignment, it is necessary to make sure that there is not a remarkable displacement in the vertical direction. The maximal deflection is around 0.0007119 mm, causing no problem in the designed system.

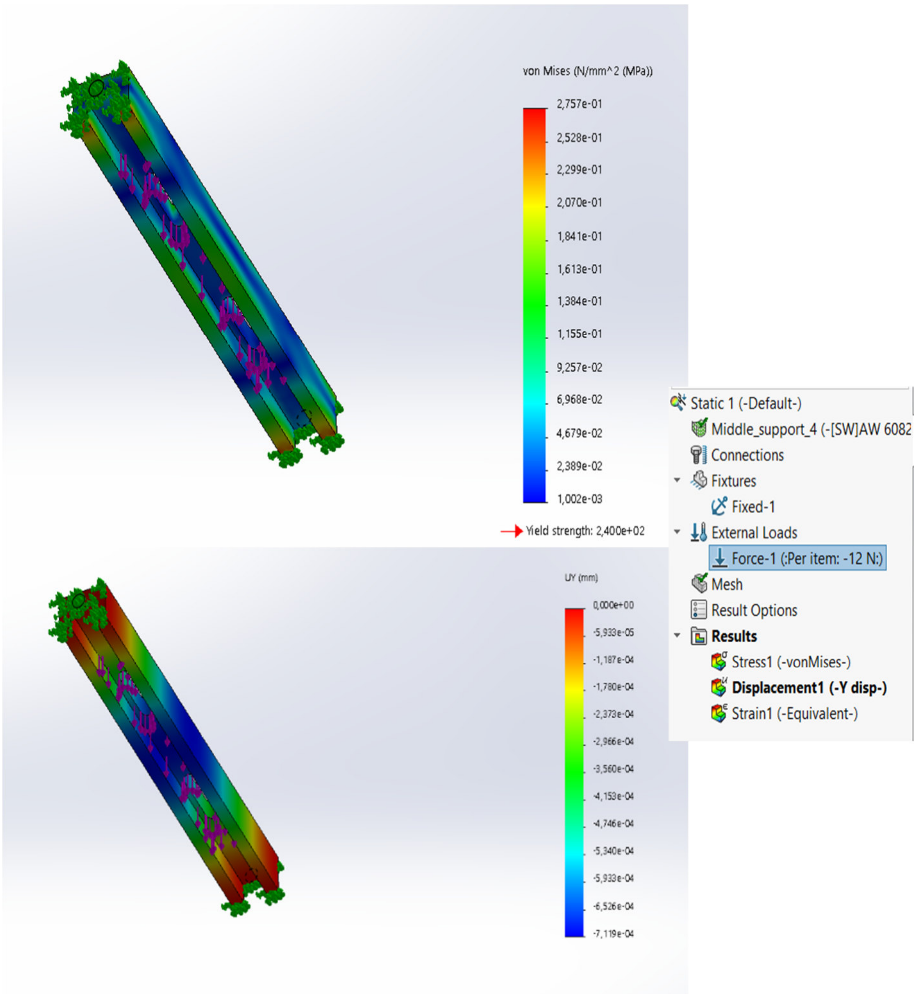


Figure 96: FEM analysis for the middle support holder.

Plate bridge (Figure 97)

The part is fixed at the holes. An external load of 27,5 N is the total weight divided by four of the parts that is assembled under the plate of the bridge, which is used as a reference to check the output of the analysis.

von Mises

As previously mentioned, the yield point has a value of 240 MPa. The max value that occurs is 11,8 MPa, which is a lot less than the yielding point. Concluding that there is no problem regarding the stress here.

Displacement

To avoid misalignment, it is necessary to make sure that there is not a remarkable displacement in the vertical direction. The maximal deflection is around 0.08694 mm, causing no problem in the designed system.

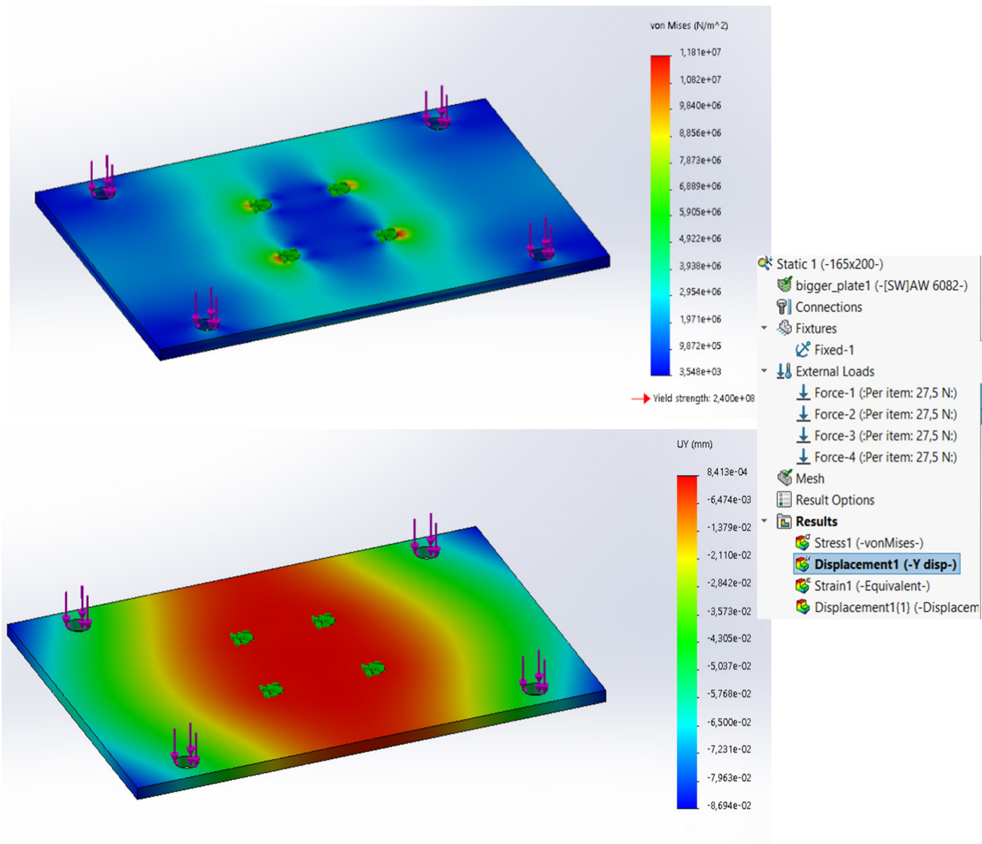


Figure 97: FEM analysis for the plate bridge.

4.3.3 Standard components used

Besides the designed parts, a lot of standard components are also used, such as cylinders, bolts, nuts, etc. In the following text, all the standard components for sub-assemblies are defined.

Gripper system

The standard components that are used in the gripper system (Figure 98) can be found in Table 18.

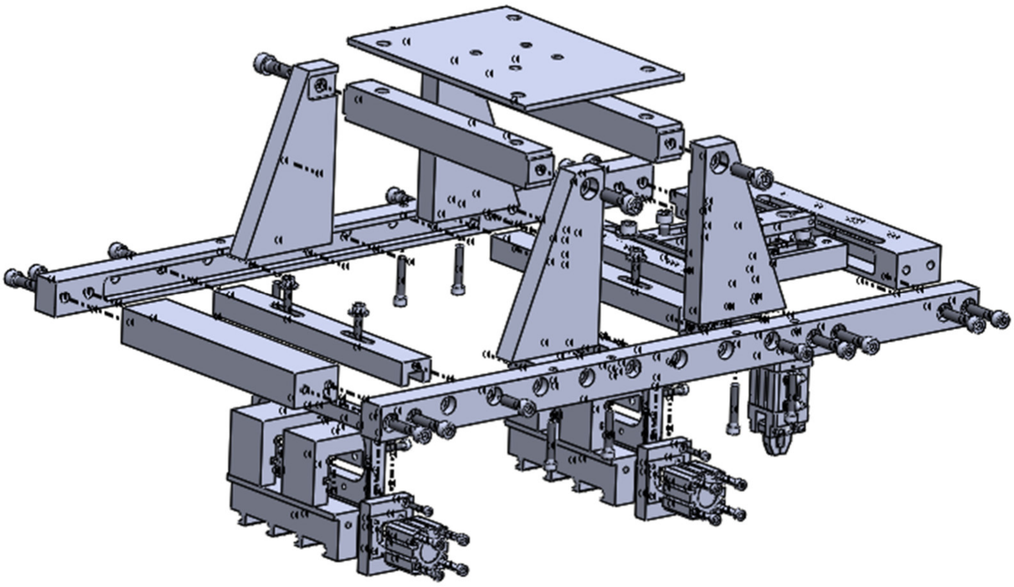


Figure 98: Standard components used in the gripper system (exploded view).

Table 18: Standard components used in the gripper system.

Description	Standard	length	QTY
Socket head screw	ISO4762	M4x20	4
Socket head screw	ISO4762	M5x25	10
Socket head screw	ISO4762	M6x35	8
Socket head screw	ISO4762	M6x25	4
Socket head screw	ISO4762	M8x35	12
Socket head screw	ISO4762	M8x25	6
Socket head screw	ISO4762	M8x16	4
Socket head screw	ISO4762	M10x30	4
Plain washer	ISO10669	7.15-N	4
Plain washer	ISO10669	8.8-N	4
CDQSB20-5DM			2
CDQS20-CQ-M5x35L			8
D-M9PSAPC-595			4

As mentioned earlier with the designed componentes, the quantities that are mentioned here are for one gripper system. For the complete manipulator, for one injection machine, it will be needed two gripper systems.

Scrap gripper

The standard components that are used in the scrap gripper (Figure 99) can be found in Table 19.

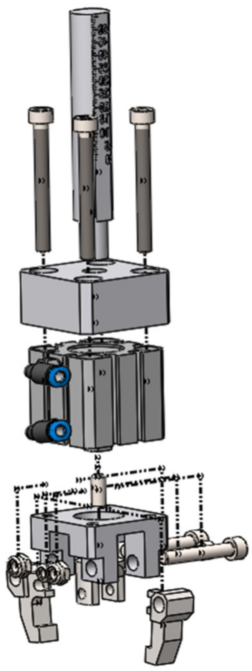


Figure 99: Standard components used in the scrap gripper (exploded view).

Table 19: Standard components used in the scrap gripper.

Description	Standard	Length	QTY
Socket head screw	DIN912	M5x30	2
Socket head screw	ISO4762	M4x25	1
Socket screw flat point	DIN913	M5x12	1
CDQSB20-5D			1
D-M9PSAPC-595			2

There are four scrap grippers in the two required gripper systems that are required in the whole manipulator for one injection machine.

Lever system

The standard components that are used in the scrap gripper (Figure 100) can be found inTable 20.

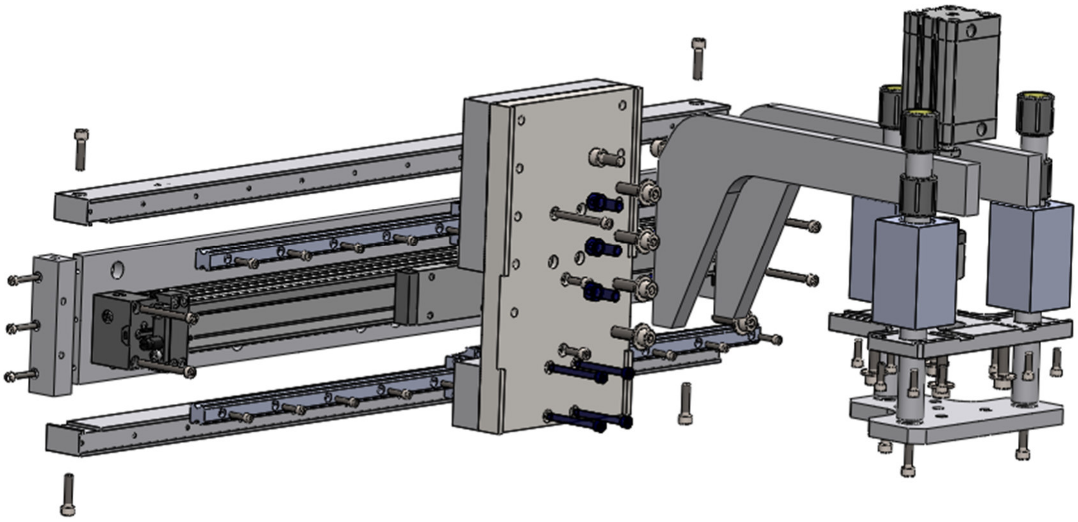


Figure 100: Standard components used in the scrap gripper (exploded view).

Table 20: Standard components used in the lever system.

Description	Standard	Length	QTY
Socket head cap screw	ISO4762	M4x16	22
Socket head cap screw	ISO4762	M4x25	6
Socket head cap screw	ISO4762	M5x16	14
Socket head cap screw	ISO4762	M5x50	12
Socket head cap screw	ISO4762	M6x25	7
Socket head cap screw	ISO4762	M8x20	8
Socket head cap screw	ISO4762	M8x30	12
Plain washer	ISO10669	8.8-N	12
536296 ADN-40-50-A-P-A			1
INAFAG_KH20			6
HGW15CA1R630ZAC			2
MY1B25-500AZ			1
6140 FK-M10X1.25			1
SMT-8M-A-PS-24V-E-0,3-M8D			2
D-M9PSAPC-595			2

As mentioned before, the manipulator system consists of two lever systems for one injection machine. The quantities that are mentioned above are only for one lever system.

Assembly gripper + lever + energy chain

To make the connection between the gripper and lever system, some standard components are used as well for connecting the energy chain (Figure 101). These are defined in Table 21.

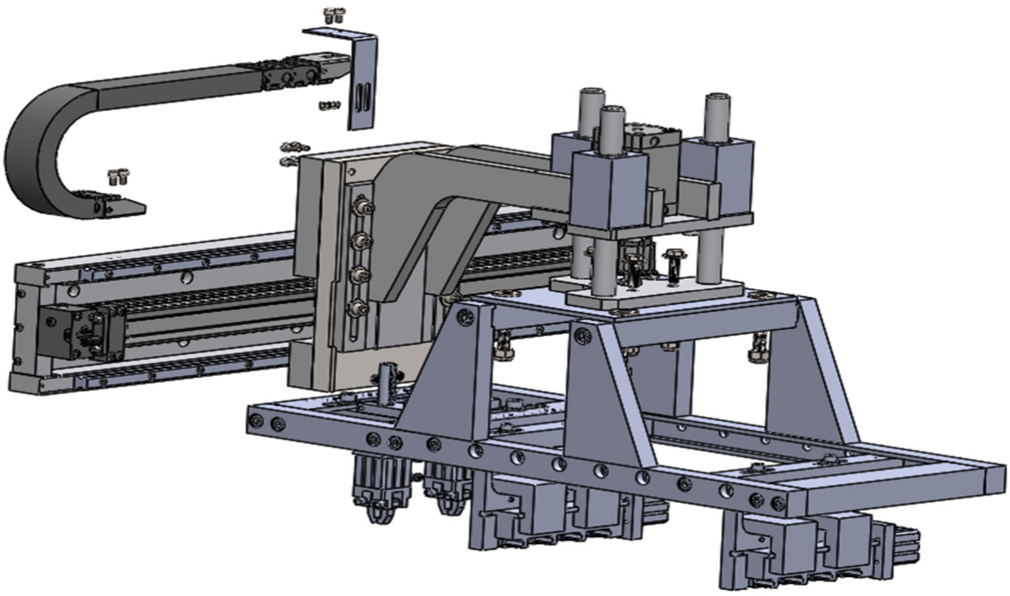


Figure 101: Standard components used in the connection between the gripper and lever system (exploded view).

Table 21: Standard components used in the connection between the lever system, gripper system and the energy chain.

Description	Standard	Length	QTY
Hex bolt grade b	ISO4015	M10x50	4
Hex bolt grade b	ISO4015	M8x30	4
Torque nut	ISO7040	M8	4
Torque nut	ISO7040	M10	4
Plain washer	ISO10673	11-N	4
Plain washer	ISO10669	8.8-N	4
300A025060_A300A025KM_500_01			1
Socket head cap screw	ISO4762	M5x10	4
Socket head cap screw	ISO4762	M5x12	4
Torque nut	ISO7040	M5	2

As earlier mentioned, the quantities that are mentioned above are considering the connection between one energy chain, one gripper system and a lever system. Thus, for the complete manipulator, we will need to take this into consideration.

Jigs

The standard components used in the jig for the first (Figure 102) and second injections (Figure 103) are defined in Table 22 and Table 23.

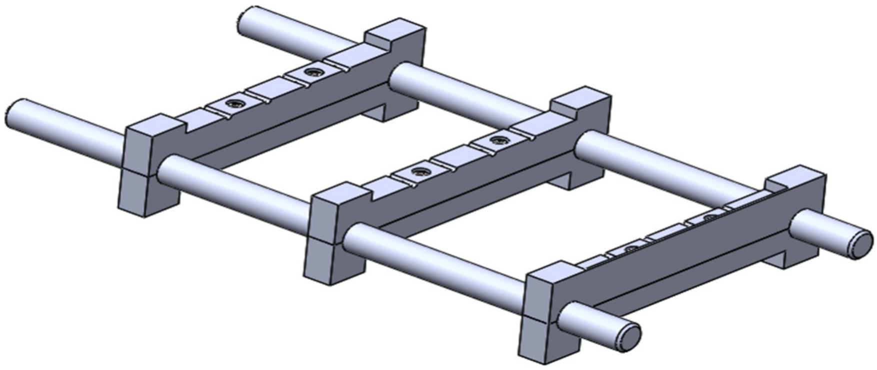


Figure 102: Standard components used in the gabarrit for the first injection.

Table 22: Standard components used in the jig for the first injection.

Description	Standard	Length	QTY
Socket head cap screw	ISO4762	M6x35	6
Magnets			12

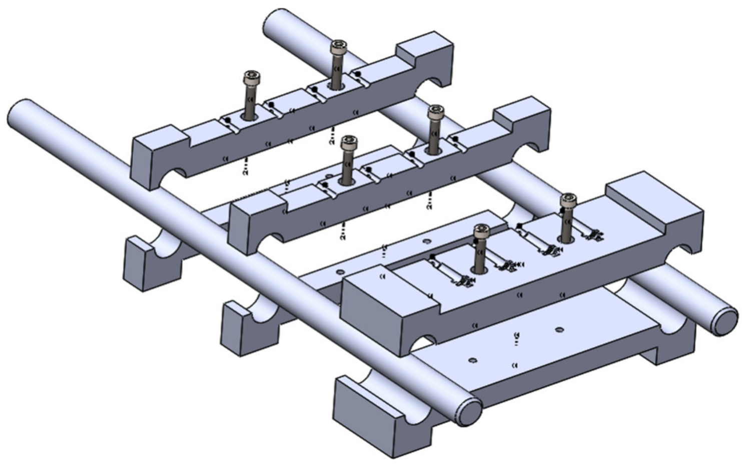


Figure 103: Standard components used in the jig for the second injection.

Table 23: Standard components used in the jig for the second injection.

Description	Standard	Length	QTY
Socket head cap screw	ISO4762	M6x35	6
Magnets			12

The quantities described above are for the complete manipulator system as we only designed these two jigs for the manipulator system.

Frame connection to lever system + gripper system +feet

The standard components used to make the connection to the lever and gripping systems, as well as feet (Figure 104), are defined in Table 24.

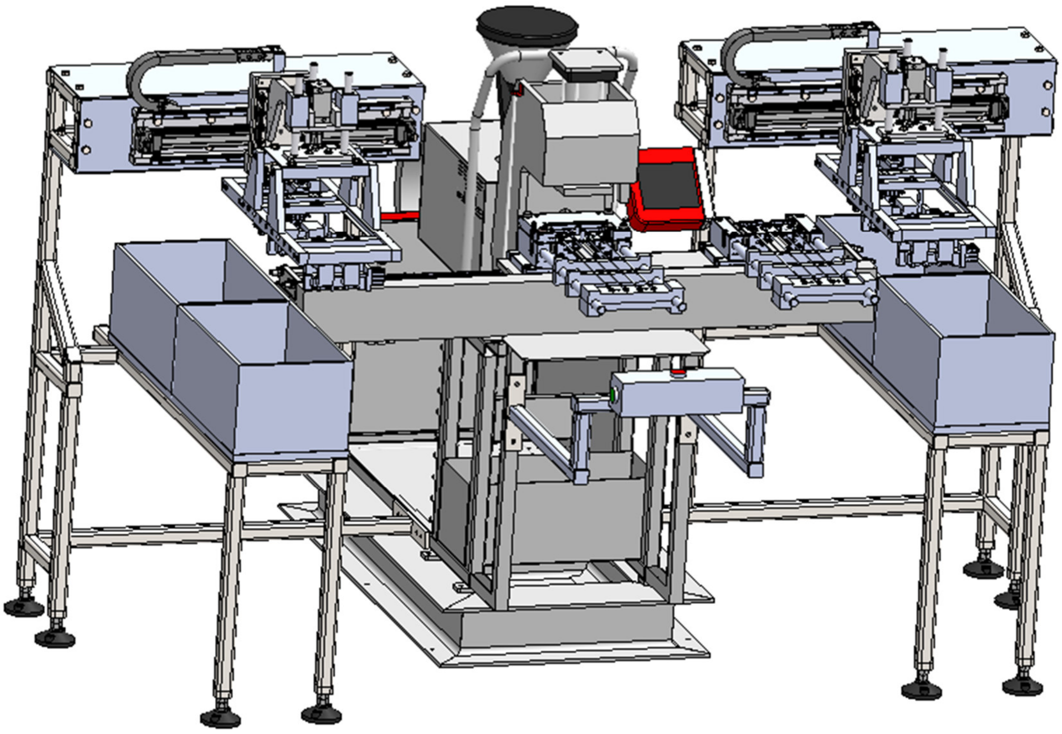


Figure 104: Standard components used in the connection between the frame and the lever- and gripping systems.

Table 24: Standard components used in the connection of the frame to the other systems.

Description	Standard	Length	QTY
Hex screw grade c	ISO4018	M12X60	24
Hex screw grade c	ISO4018	M12x30	24
Torque nut	ISO7040	M12	48
4901/4/C			8

Safety system

All the standard components used considering the frame for the safety equipment (Figure 105) are defined in Table 25.

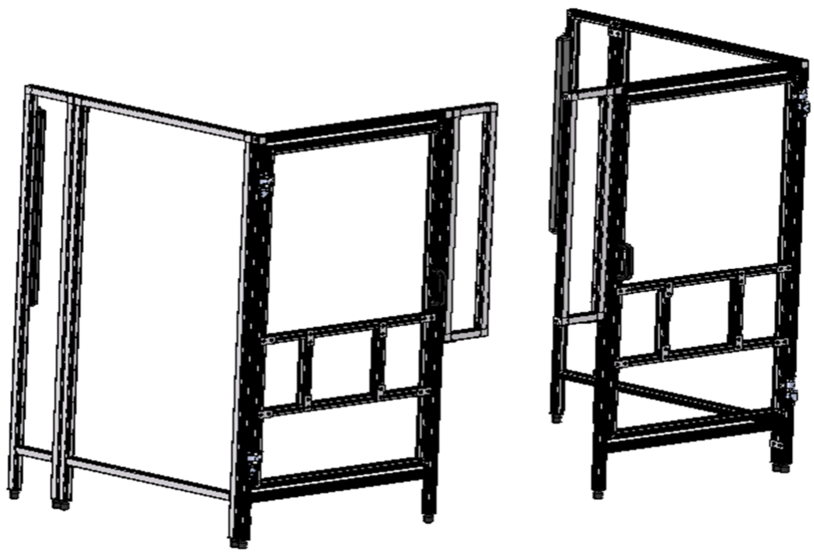


Figure 105: Standard components used in the safety system.

Table 25: Standard components used un the safety system.

Description	Standard	Length [mm]	QTY
Torque nut	ISO7040	M8	8
T-bolt	DIN186	M8x30	8
0019657_Handle_PA_160			2
0019664_Adjustable_Foot_8_PA_h=50			12
0043692_Clamp_profile_8_40x40_E		40x40x1650	4
TESK-ZS			2
TESK-SU-12ST1			2
0047463_Bracket_80x40x20_Zn			2
0068096_Fastening_Set_8_2-5mm_with_Countersunk_Screw_M8			52
0066635_Bracket_8_40_flat			26
0043692_Clamp_profile_8_40x40_E		40x40x150	4
0043692_Clamp_profile_8_40x40_E		40x40x1100	4
0043692_Clamp_profile_8_40x40_E		40x40x330	4
0042995_Clamp_Profile_8_40x40-180		40x40x826	4
0043692_Clamp_profile_8_40x40_E		40x40x826	4
0061797_Profile_8_40x40_F14_light		40x40x915	4
0061797_Profile_8_40x40_F14_light		40x40x2000	4
0043692_Clamp_profile_8_40x40_E		40x40x200	4
0044476_Clamp_Profile_fastener_8_40x40_E			28
0043692_Clamp_profile_8_40x40_E		40x40x915	4
0043692_Clamp_profile_8_40x40_E		40x40x2000	8
Corrugated mesh			

4.3.4 Assembly procedure

The assembly needs to be correctly performed to prevent equipment malfunction or even catastrophic failure. Thus, the entire assembly needs to be carried out according to the mechanical design. There were already some exploded views seen earlier that can help but the summary of the sub-assemblies and the whole assembly will help again to perform correctly the final assembly.

Scrap gripper

The scrap gripper is assembled according to the exploded view, as seen in Figure 106. The comments next to the figure refer to the fastening components that are used.

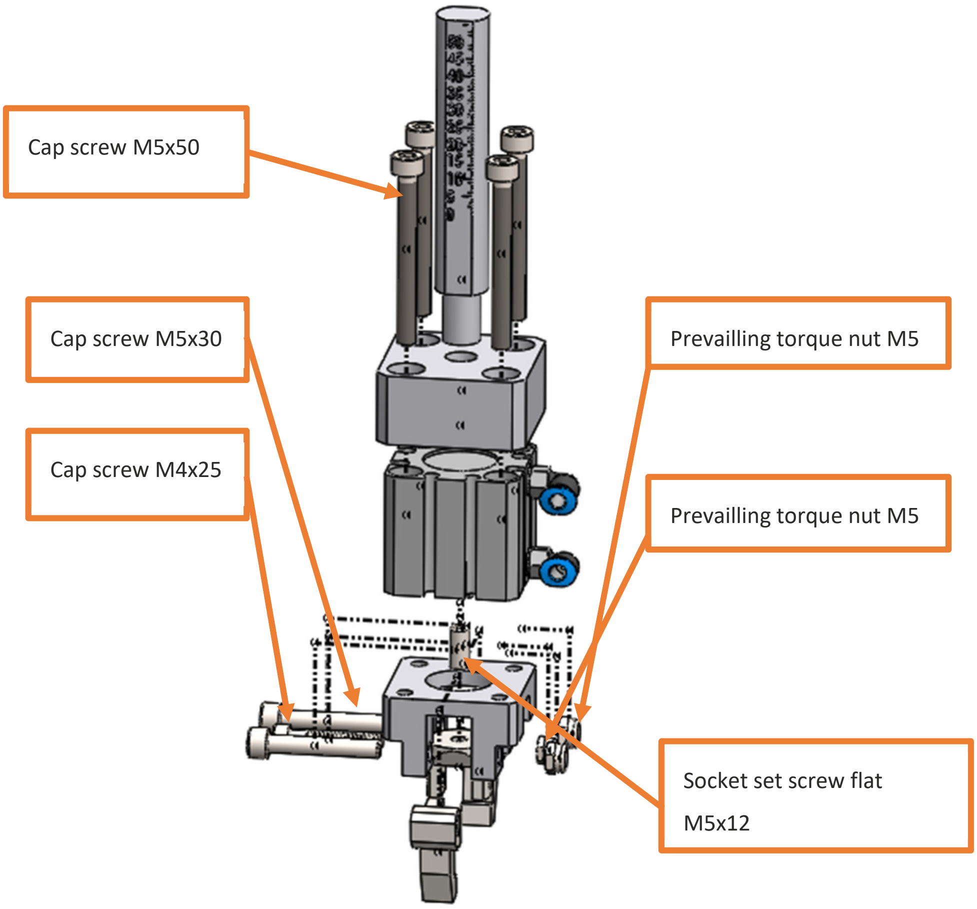


Figure 106: Assembly of the scrap gripper.

Gripper system

The gripper system is assembled according to Figure 107. The comments on the side are the fastening components needed to be used.

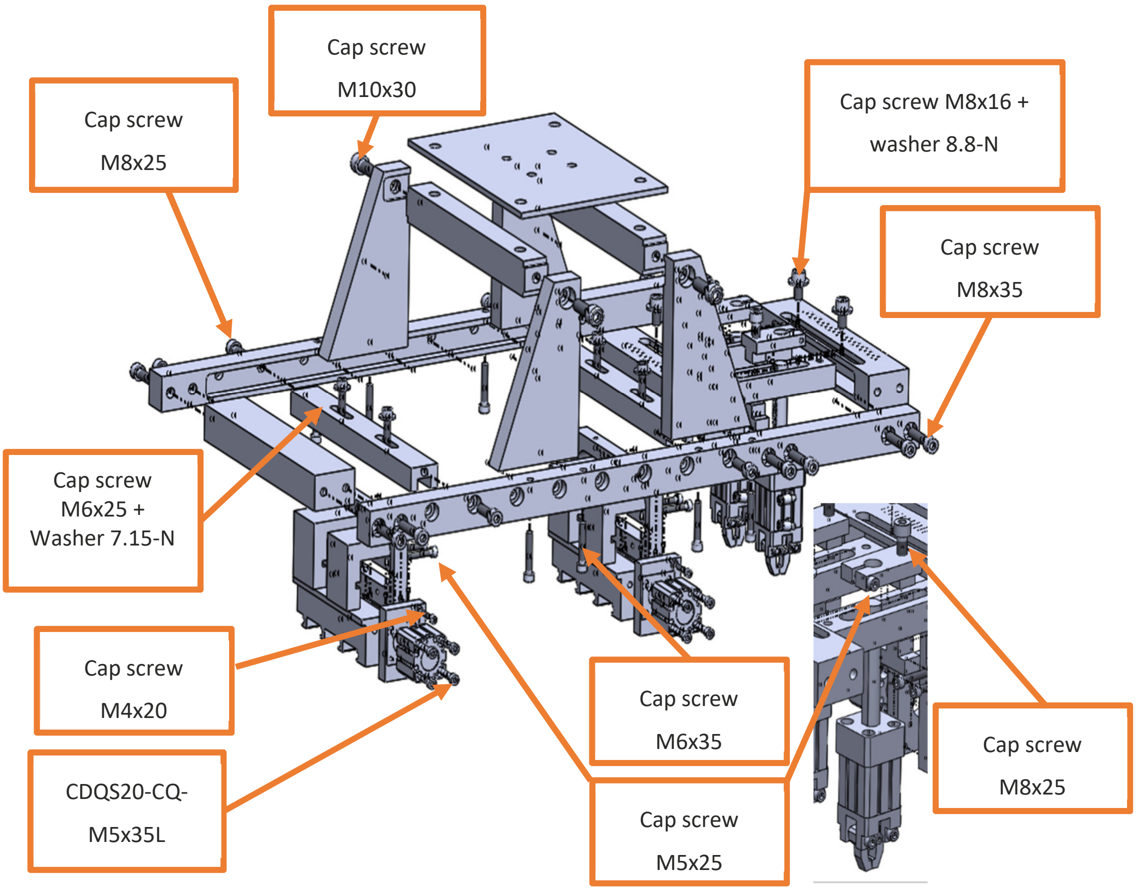


Figure 107: Assembly of the gripper system.

Lever system

The lever system is assembled according to Figure 108. The comments on the side are the fastening components that are used.

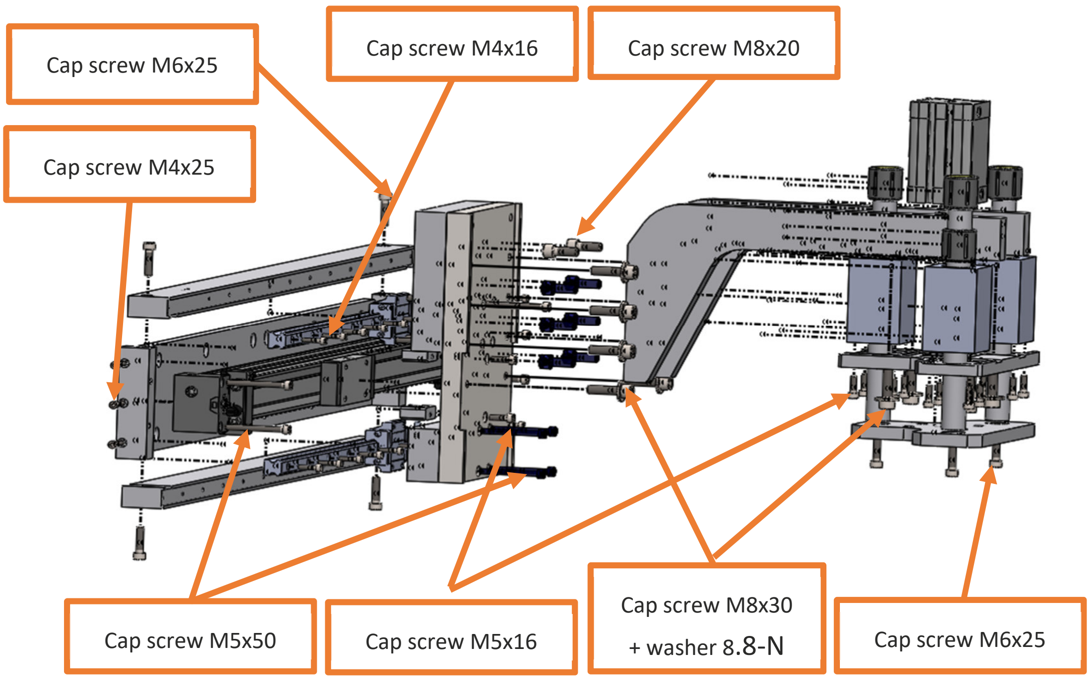


Figure 108: Assembly of the lever system.

Connection lever system to the gripper system and energy chain (caterpillar)

The connection between the energy chain, lever system and gripper system are assembled according to Figure 109. The comments on the side are the fastening components that are used.

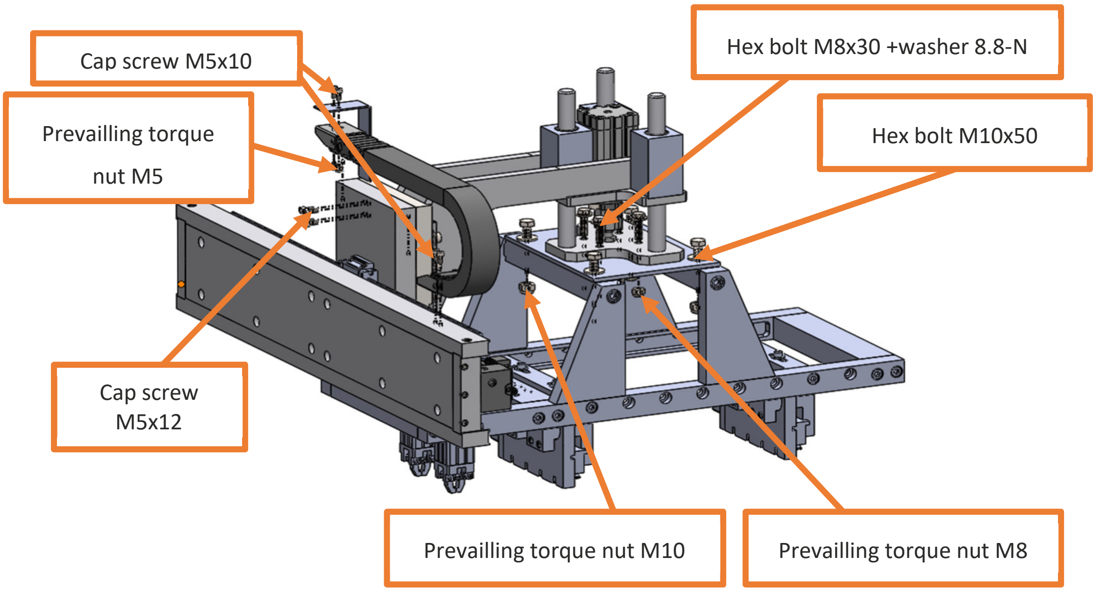


Figure 109: Assembly of the connection of the energy chain, lever system and gripper system.

Connection of the steel structure to the rest of the previous sub-assembly

The connection between the steel structure and the previously described assembly can be seen in Figure 110. The comments on the side are the fastening components that are used.

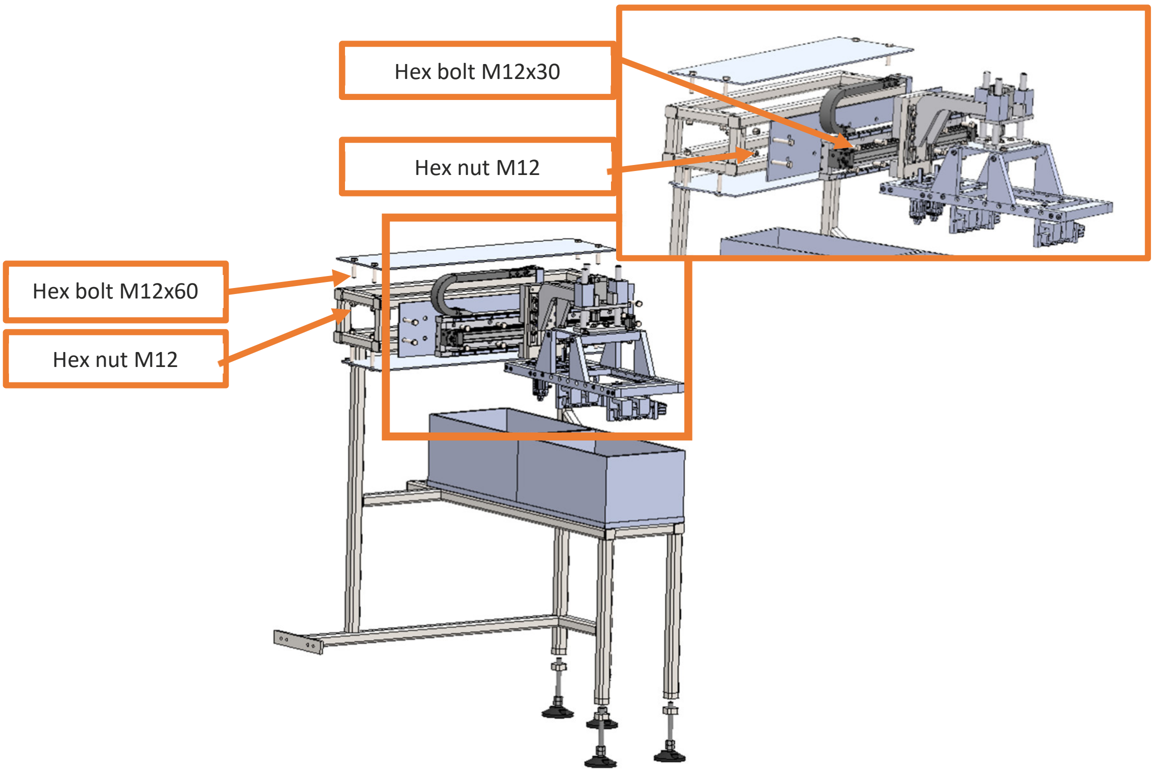


Figure 110: Connection of the sub-assembly to the steel structure.

Overview of the whole assembly

An overview of the whole assembly can be seen in Figure 111.

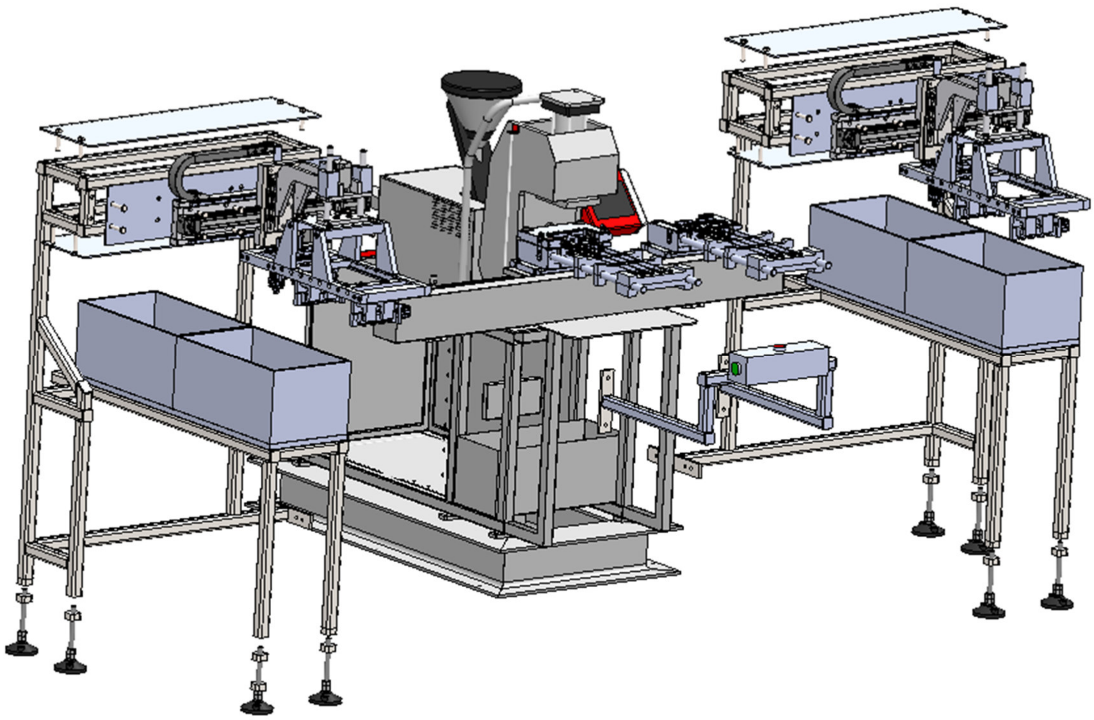


Figure 111: Final assembly of the manipulator system.

4.4 Automation design

4.4.1 Grafcet diagram (mode of operation)

Looking at Figure 112, the working of one side of the machine is explained. Thus, the working principle is as follows:

- Push start;
- Cylinder G is recognised in position g1 after the injection;
- Cylinder A, B, C, D, E, F in postion a0, b0, c1, d1, e0 and f0;
- Cylinder B goes down from b0 to b1 to go over the conduits;
- Clamping of the conduits due to cylinders C,D,E,F are going from postion c1, d1, e0, f0 to c0, d0, e1, f1;
- Cylinder B goes up from b1 to b0;
- Cylinder A goes from left to right, from a0 to a1;
- Clamps are opened to lose the conduits due to cylinders C, D, E, F are going from position c0, d0, e1, f1 to c1, d1, e0, f0;
- Everything goes back to the first position,e.g., cylinder A, B, C, D, E, F in postion a0, b0, c1, d1, e0 and f0.

This routine goes the same way for the other side of the machine, when cylinder G is in position g0 instead of g1 after the injection.

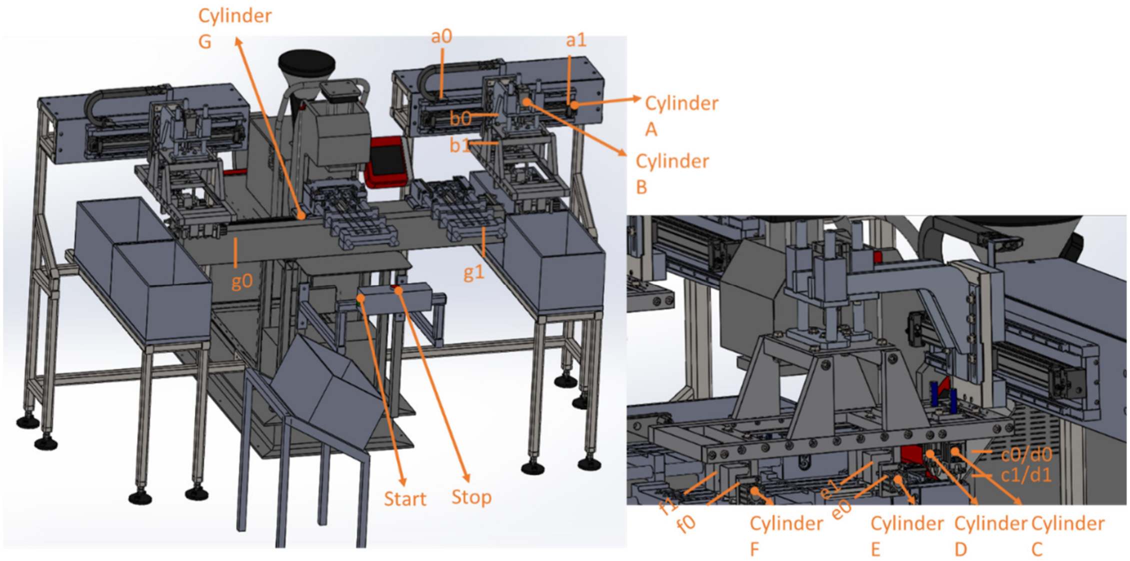


Figure 112: Explanation of the movements of the cylinders (1-side).

Looking at Figure 113 the actuators (cylinder) are all given a name used to explain all of the movements in a graphcet diagram (Figure 114).

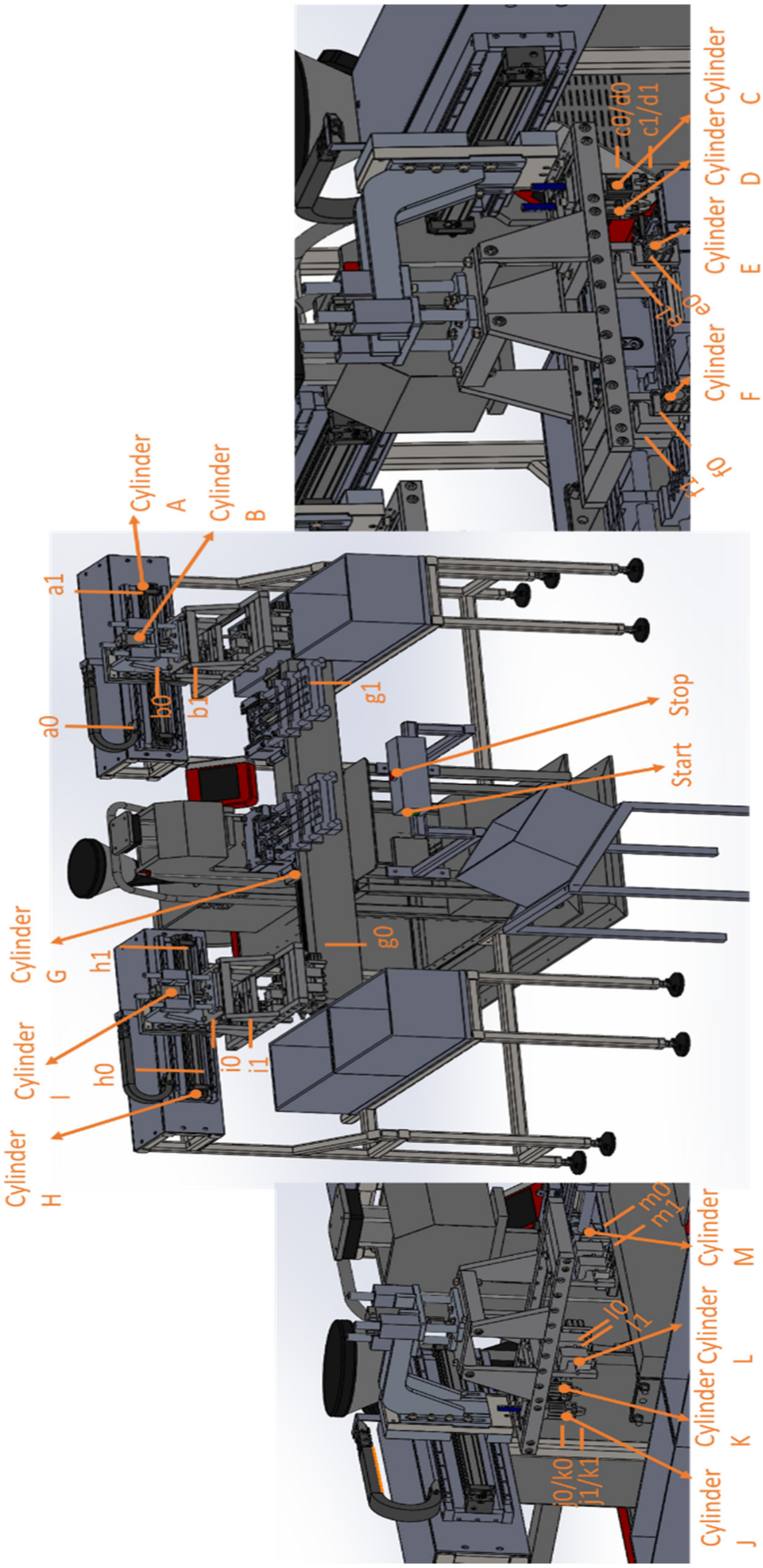


Figure 113: Complete system with actuators (cylinders).

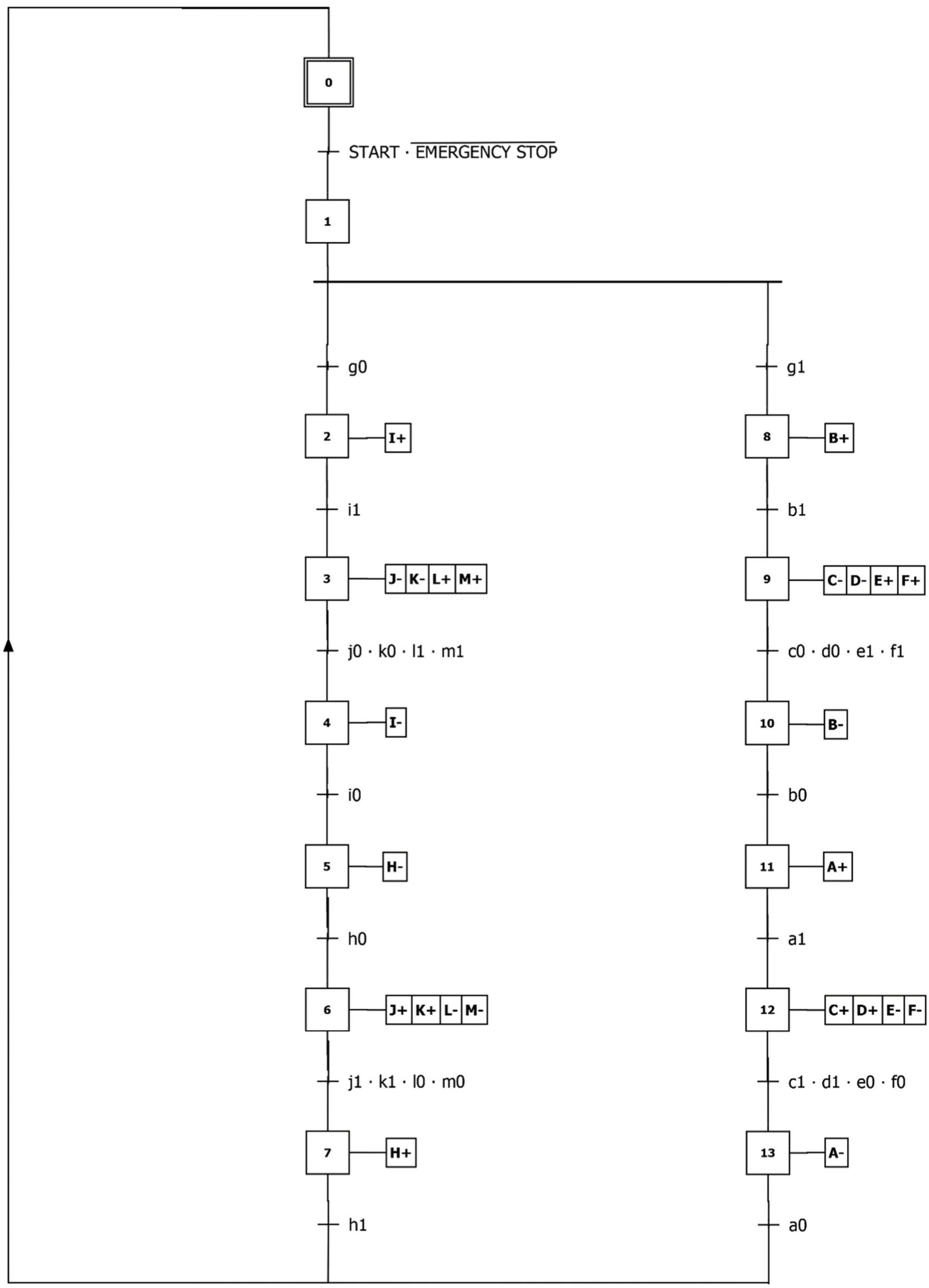


Figure 114: Grafcet diagram of the complete manipulator in symbols

4.5 Energy consumption

As earlier mentioned, the energy consumption was one of the reasons that the company purchased the new "BabyPlast" injection machines. A comparison has been carried out between the current situation and how the future situation will look like between the old injection machines (Fiser) with a capacity of eight injections at once and the new injection machines (BabyPlast) with a capacity of four injections at once. The comparison will include the energy consumption and the parts produced per hour.

Table 26: Electrical data collected from the injection machines.

	Babyplast®		Fiser®	
	Time (s)	**I(A)**	**Time (s)**	**I(A)**
	0	2,1	0	25,1
	1	1,9	1	27,1
	2	1,9	2	34,7
	3	2,1	3	35,2
	4	3,8	4	29,1
	5	5	5	46,6
	6	3,1	6	37,5
	7	3,1	7	29,7
	8	3	8	39,7
	9	2,9	9	41
	10	2,7	10	32,1
	11	3,4	11	26,7
	12	4,5	12	25,2
	13	4,7	13	25,2
	14	3	14	25,1
	15	2,9	15	25,1
	16	3,6	16	28,1
	17	4,4	17	27,5
	18	4,5	18	25,5
	19	4,9	19	25
	20	5,2	20	25
	21	4,4	21	31,5
	22	4,6	22	34,7
	23	5,2	23	34,6
	24	3,5	24	37
	25	2,5	25	46,2
	26	2,3	26	41,7
	27	2,1	27	39,2
	28	2,1	28	39,4

	Babyplast®		Fiser®	
	Time (s)	I(A)	Time (s)	I(A)
	29	2,1	29	35,5
	30	1,9	30	42,5
	31	2,1	31	27
Average current (A)		3,30		32,67

The other information needed to calculate the energy consumption can be found on the nameplates (Figure 115).From the nameplates (Figure 115) we can see that the machines are both working at 400V at 50Hz. The average amperage is calculated by taking the sum of the amperages divided through the time interval. A summary of the collected information from the nameplates and collected data can be found in Table 27. The power and energy consumption of the injection machine was calculated as followed:

$$P[W] = \sqrt{3} * U * I * Cos\varphi \qquad (1)$$

$$E[kWh] = \sqrt{3} * U * I * Cos\varphi * 24/1000 \qquad (2)$$

where Cosϕ=1 in the equations, as we are only converting it to resistive energy.

Figure 115: Nameplate injection machines.

Table 27: Energy consumption using the nameplates and the collected measurement data.

	Babyplast®	Fiser®
U_{nom} (V)	400	400
I_{avg} (A)	3,30	32,67
Power (W)	2284,14	22635,74
Energy consumption of the injection machine (kWh)	54,82	543,26

From Table 27 it is possible to conclude that the energy consumption from the BabyPlast® injection machine is ca. 10x smaller or there is a reduction of 89,9% in energy consumption. However, to compare the current situation to the future situation, it is needed to take two

BabyPlast® injection machines into account. The company has the objective of 1000 injections per hour for the Fiser® injection machine and 750 injections per hour for the BabyPlast® injection machine. But it is really optimistic to think we can just mulitiply the objective, of 750 injections, by 2. In order to make a correct assumption, a cycle time overview has been set out (annex 7.7). In the annex it is possible to see the theoretical speed of the cylinders, the practical injection time and the practical time to put in the conduits. If it is set out these times, it is possible to observe some overlap in the cycle times of the machines. Thus, the machines will not work at full capacity. Nevertheless, checking how many overmoulded products can be made per minute and converting it to an hour gives rise to the results presented in Table 28. It is defined the energy consumption and the injections per hour in the two situations. A decrease of 79,82% in energy consumption and an increase of 12% in parts injected per hour has been identified.

Table 28: Comparison between the current and future situation in the function of energy consumption and injections per hour.

	Current situation **1 x Fiser®**	**Future situation** **2 x Babyplast®**
Energy consumption[kWh]	543,26	109,64
Overmoulded parts per hour [#]	1000	1120
Reduction of energy consumption [%]	79,82%	
Increase of produced parts [%]	12%	

The increase in injected parts and the reduction in energy consumption make it clear why this project was initiated.

4.6 Manual of operation and safety conditions

Before putting the equipment into operation, we need to check some points such as :

- Check that there are no obstructions for the mobile equipment and the linear guiding elements, to avoid eventual failures;
- Confirm that the only conduits present in the equipment, are from the reference that is intended to be produced;
- Clean the workstation.

After the previously mentioned checks, the operator still needs to perform some actions such as the setup of the equipment seen in Table 29.

Table 29: Actions that need to be carried out before putting the machine into operation.

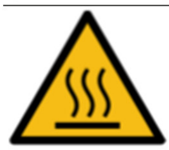
Description
Adapt the jig to the desired reference and length of conduit that needs to be produced.
Replacement of the injection mould to the type of end of conduit that needs to be overmoulded.
Change the distance between the grippers to the required position depending on the length of the conduit.
Put the equipment into operation.

The operation of the machine must be in a way that there are no situations that could damage the equipment or even more important, damaging the physical health of the operator. To obtain this "safe" way of working we need to comply with certain standards. During the operation of the machine equipment, safety rules need to be followed. Some fundamental instructions that need to be followed:

- Getting familiar with the functions of the machine;
- Do not remove mobile and / or fixed protections as well as safety devices present in the equipment, without the power sources being properly disconnected;
- Regularly check that the guards and safety devices are in the correct position and in perfect working condition;
- Do not put your hands next to moving elements;
- Maintenance or cleaning of the machine must not be carried out while the machine is in operation. Moving elements can cause accidents;
- Keep the equipment and the surrounding area clean and free of residues or objects;
- Keep the electrical panel closed;
- Respect the signs on the machine.

Respecting the signs on the machine is important to ensure the safety and wellbeing of the operator. Through these indications, the operator will be able to adapt his behavior in order to avoid accidents at the worksite. In Table 30 some of the signages found in the equipment are presented. Safety signs are intended to make you aware of hazards, obligations or prohibitions.

Table 30: Signages present on the equipment.

Signage	Description
OBLIGATION	
	Protective goggles. Mandatory use of eye protection when using the equipment.
	Hearing protection. Mandatory use of hearing protection while the equipment is in operation.
	Protective clothing. Whenever in contact with the equipment the operator must wear protective clothing.
	Protective gloves. Informs the operator of mandatory use of protective gloves while operating the equipment.
	Protective helmet. The use of a protective helmet is mandatory while carrying out maintenance actions.
DANGER	
	The danger of projections. Warns the operator of the existence of a place where there may be particle projection.
	General danger. Signs that warn the operator of the existence of various hazards in the location where the sign is.
	Hot surfaces. Warns the operator of hot surfaces on the equipment.
	The danger of electrocution. When an action needs to be performed where this signal is present, it must be ensured that the equipment is not powered by electrical current.
	Risk of crushing due to displaceable components. Where these signs are present, it is strictly forbidden to place your hands or any part of your body if the equipment is in operation.

Regarding the emergency stops, they should not be used as a normal way to turn off the equipment. Only activate them in dangerous situations, both for the equipment and the operator itself. Resetting the equipment may not start the cycle. This action will be carried out by the operator using the start button.

4.7 Manual of maintenance

The definition of maintenance is, according to BS EN 13306:2017, “A combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function.”
Good maintenance can be qualified as guaranteeing the previously mentioned conditions against the lowest cost possible. Maintenace should be taken into account from the design phase onwards. When the machine is put into production, we will need to monitor the machine permanent or periodic to assure the health of the equipment. When a defect or impermissible wear occurs, repairs or preventive actions need to be carried out. A bunch of those actions can be found in Table 31.

Table 31: Preventive actions.

Action	**Periodicity**
Control of air leaks in all pneumatic equipment (Tubes, connectors and Actuators).	Monthly
Check the tightness of screw connections.	Every six months
Lubrication of moving parts.	Monthly
Check linear guidance systems for debris and lubricate the system.	Weekly
Inspection of electronic components.	Quarterly
Checking the wear of the parts in use.	Quarterly
Cleaning of equipment and work station.	Weekly
Conducting tests and verification tests after preventive actions.	Every six months

By following the earlier preventive actions, it will certainly be possible to assure a greater lifetime for the equipment. However, following these guidelines can not prevent an equipment break down at some point. In this case, it will be necessary to fix it as efficiently and quickly as possible.

Finally, the safety of the operator and eventually the maintenance technician needs to be assured. To ensure this, some rules need to be followed such as mechanical blocking, cut-off electricity supply, avoiding the unwanted activation of the equipment during the maintenance. The operator and technician also need to take signages previously mentioned (Table 30) into account.

4.8 Budgeting

4.8.1 Methodology of total cost calculation of the manipulator system

The price calculation is split up into two main sections, the price quotation of standard components and the price of the designed components. The price quotations of the standard components can be found in annex 7.1. The cost of the designed components is based on an estimated value of the price per kg of the material that is used and an estimated cost of the machining process needed to produce the components (annex 7.3.5 and annex 7.3.6). Nevertheless, to have an idea of ordering material in the future, the parts that are needed were put in a nesting program to see how much of standardized plates will be needed (annex 7.4) .

4.8.2 Return on investment (ROI)

The evaluation of the efficiency of a project is done by calculating the ROI [36]. Data concerning the current yearly operating cost (1x Fiser) is collected from Fico Cables (Table 32).

Table 32: Data on the yearly costs of the current situation.

	Operator(s)/production line	Cost/year/shift	Shifts	Cost/year
Operator salary	1	14 000,00 €	3	42 000,00 €
Energy				27 939,05 €
Set-up				28 800,00 €
Raw material waste in set-up and start of production				960,00 €
Raw material consumption				5192,00 €
Maintenance				7003,00 €
Total				**111 894,05 €**

Data concerning the expected future yearly operating cost (2x BabyPlast®) can be seen Table 33.

Table 33: Data on the yearly costs of the future situation.

	Operator(s)/production line	Cost/year/shift	shifts	Cost/year
Operator salary	1	14 000,00 €	3	42 000,00 €
Energy				5638,62 €
Set-up				19 200,00 €
Raw material waste in set-up and start of production				122,80 €
Raw material consumption				2546,00 €
Maintenance				1050,00 €
Total				**70 557,42 €**

Table 34: Comparison energy cost per year.

	Current situation	Future situation
Injection machine	1 x Fiser®	2 x Babyplast®
Energy consumption[kWh/dag]	543,26	109,64
Total days per year	365	365
Cost [€/kWh]	0,14 €	0,14 €
Total energy cost/year	**27 939,05 €**	**5638,62 €**

- Lifetime of the project: 8 years.
- The project will reduce the amount of consumed energy and increase the production rate.

Calculation of the ROI:

Knowing the total cost of the project (36 047,95 €), the return of investment can be calculated.

$$ROI = ((Gain\ from\ investment - Cost\ of\ investment)/(Cost\ of\ investment)) * 100 \quad (3)$$

The costs that can be cut off the current situation over the lifetime of the project is defined as the gain from the investment. This is a total of 330 693,04 € = (8*41 336,63 €). Due to the increase in production rate, some extra gains are accomplished. Assuming there is 1 € gain on a complete Bowden Cable, 15% of gain is made on the overmoulded conduit resulting in a total gain for each overmoulded conduit of 0,15 €. As we concluded before the production goes from 1000 to 1120, an increase of 12% in production.

$$1000\ \frac{injections}{hour} = 8\ \ 760\ 000\ \frac{injections}{year}$$

$$1120\ \frac{injections}{hour} = 9\ 811\ 200\ \frac{injections}{year}$$

$$9\ 811\ 200\frac{injections}{year} - \ 8\ 760\ 000\frac{injections}{year} = \ 1\ 051\ 200\frac{injections}{year}$$

This results in an extra gain of (1 051 200 x 0,15 €) 157 680,00 € each year. Over the lifetime of 8 years it is 1 261 440,00 €. Putting this together with the saved money on operating costs it is resulting in (1 261 440,00 € + 330 693,04 €) 1 592 133,04 € of gain.

The cost of investment is the total cost of the project (36 047,95 €).

$$ROI = ((1\ 592\ 133{,}04€ - 36\ 047{,}95\ €)/36\ 047{,}95) * 100 = 4316{,}70\%$$

Looking at the results of the ROI, the efficiency amounts 4316,70% which means that it is a smart investment.

The payback period of the investment is:

$$\frac{199\ 016{,}63\ €}{1\ year} = \frac{36\ 047{,}95\ €}{X\ year} \rightarrow X = 0{,}18\ year = 66\ days$$

CONCLUSIONS

5 Conclusions

The automation of processes that can replace manual labour is an important factor in the industry. By implementing automation, it is possible to increase the productivity and quality of the products while reducing the production cost per unit. The automotive sector is competitive.

This is why the manufacturers of Bowden cables, are always seeking for improvements in their production process. They want to increase the production capacity but also staying flexible to be able to make different product references with different lengths. Also the greener aspect of the concept is important for the company. Thus, the energy reduction that is accomplished using the smaller injection machines (Babyplast®) is really important.

The design of the equipment is done by analyzing different concepts in function of productivity, quality, safety, cost, and so on. The goals concerning this concept are described below, as well as the achievements made regarding each goal, as can be seen in Table 35.

Table 35: Evaluation of the goals

Goal	Conclusion	Evaluation
Being able to make different lengths of the same reference.	The developed manipulator and jig allows us to carry out one reference with different lengths.	✓
Good accessibility for maintenance and cleaning of equipment.	There are two doors in the back of the machine to provide good accessibility.	✓
Eliminating the task of taking out the conduits of the mould and putting them in a storage box.	With the older equipment is was necessary to take out the overmoulded conduits and put them in storage boxes. In the new concept, this operation is done automatically.	✓
Present the lowest possible investment cost, safeguarding an optimal compromise between the productivity and the necessary construction cost (investment).	Taking all the factors mentioned earlier into consideration, the investment is paid back in a short period (66 days).	✓

Goal	Conclusion	Evaluation
Guaranteeing safety for the operator in case of failure of any the systems	The equipment follows Directive 2006/42 / EC of the European Parliament and of the Council of 17 May 2006, which ensures that the operator's safety is ensured	✓
Using the supplier preferably used by the company.	Most of the suppliers asked by the company are followed such as SMC, ITEM, Brevetti Stendalto, …	✓
One person needs to be able to work at two BabyPlast injection machines.	By taking the previously mentioned manual repetitive task of taking out the conduits away by automating the task, one person can put in the conduits at two BabyPlast injection machines.	✓
Reduction in energy consumption.	By implanting the new Babyplast® machines the energy consumption goes from 543,26 kWh to 54,82 kWh, resulting in an energy reduction of 79,82%.	✓
Improvement in the productivity of injections per hour.	The new concept has the objective to inject 1120 times per hour compared to 1000 injections per hour of the current concept. This results in an increase of 12% in injections per hour.	✓

Thus, it can be concluded that the main objectives are achieved. Primarily, that one operator will be sufficient to work at two BabyPlast® injection machines without loss in productivity.

REFERENCES AND OTHER SOURCES OF INFORMATION

6 REFERENCES AND OTHER SOURCES OF INFORMATION

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ANNEXES

7 ANNEXES

7.1 Price quotations

7.1.1 Safety design

EUROPNEUMAQ®

EUROPNEUMAQ - Equipamentos Pneum. Hidr., Lda
Rua da Senhora Mestra, 35 - N.E.S.
Serzedo VNG
4410-511 Serzedo VNG
Contribuinte: 504699563

Fico Cables, Lda
Mário Cardoso/Robin Penne
Rua do Cavaco, 115
PO Box 1075
4470-263 MAIA

Proposta

Original

Este documento não serve de factura

Número	Data	V/ Referência	Validade Proposta	Cliente	Contribuinte
ORC 1/2543	2020-05-21		60 dias	000214	500423261

Artigo	Descrição	Qtd.	Comp.	Larg.	Qt. Tot.	Un	Prazos	P. Unit.		Valor
0.0.436.92	Clamp Profile 8 40x40 E, natural	7,00	6,000	0.000	42,000	MT	15 dias úteis	27,22		1.143,24
0.0.026.30	Saw Cut for Small Cross-Sections	7,00			7,000					
0.0.429.95	Clamp Profile 8 40x40-180°, natural	1,00	3,304	0.000	3,304	MT	15 dias úteis	57,43		189,75
0.0.026.30	Saw Cut for Small Cross-Sections	1,00			1,000					
0.0.617.97	Profile 8 40x40 F14 light, natural	2,00	6,000	0.000	12,000	MT	15 dias úteis	18,21		218,52
0.0.026.30	Saw Cut for Small Cross-Sections	2,00			2,000					
0.0.680.96	Fastening Set 8 2-5mm with Countersunk	50,00			50,000	CNJ	1 a 2 dias úteis	1,04		52,00
0.0.444.76	Clamp-Profile Fastener 8 40x40 E	56,00			56,000	CNJ	15 dias úteis	12,01		672,56
0.0.474.63	Bracket 80x40x20 Zn, black	2,00			2,000	UN	1 a 2 dias úteis	5,03		10,06
0.0.666.35	Bracket 8 40 flat, white aluminium, similar t	28,00			28,000	UN	1 a 2 dias úteis	3,87		108,36
0.0.196.64	Adjustable Foot 8 PA	12,00			12,000	UN	15 dias úteis	5,26		63,12
103005763	TESK-SU-12-ST1 [1NA+2NF] (Interruptor	2,00			2,000	UN	5 a 10 dias úteis	59,36		118,72
103002968	TESK-ZS (Dobradiça adicional)	2,00			2,000	UN	5 a 10 dias úteis	16,40		32,80
0.0.196.57	Handle PA 160, black	2,00			2,000	UN	1 a 2 dias úteis	6,24		12,48
	SLC 440COM-ER-0890-35	1,00			1,000		5 a 10 dias úteis	968,33		968,33
	Preço Rede 30x30 (m2)									
0.0.428.34	Corrugated Mesh St 4mm 30x30, bright zin	1,00	1,000	1.000	1,000	MT2	5 a 10 dias úteis	23,75		23,75
0.0.475.51	Saw Cut for Panel Elements Cat. 4	1,00			1,000			11,78		11,78
PORTES VOLUME	Portes de grandes volumes	1,00			1,000					
Total										3.625,47

Condições:
Prazo de entrega válido salvo alterações de stock — Pagamento: 60 Dias TRB
Portes: Não incluídos

SWIFT: BCOMPTPL - IBAN : PT50.0033.0000.00046316991.80

Incidência	IVA	Valor Imposto
	0,00	
3.625,47 €	23,00	833,86 €

Subtotal	3.625,47 €
Despesas	
Adiantamentos	
Total IVA	833,86 €
Total em (EUR)	**4.459,33 €**

Data Carga		Hora Carga	
Local Carga	N/Instalações		
Descarga	Morada do Cliente		

Observações

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Tel.: (+351) 227 536 820 | Fax.: (+351) 227 620 335 | info@europneumaq.pt | www.europneumaq.com

7.1.2 Cylinders SMC + accessories

Nº Cotação	Data	Página
0032630910	25/05/20	2/2

Cotação

Linha	Referência SMC Descrição	Quantidade Prazo de entrega	Preço líquido unitário	Total Líquido
1  Detalhes do produto	MY1B25TFG-500AZ CILINDRO SEM HASTE ø25 C=500	2 / PCE 3 dias	185,13	370,26
2  Detalhes do produto	CDQSB20-5D CILINDRO COMPACTO ø20 C=5	4 / PCE Stock	18,56	74,24
3  Detalhes do produto	CDQSB20-5DM CILINDRO COMPACTO ø20 C=5	4 / PCE 3 dias	19,36	77,44
4 	D-M9PSAPC-595 DETECTOR DE ESTADO SÓLIDO	20 / PCE Stock	11,59	231,80
			Total Líquido (EUR)	753,74
			Total (EUR)	**753,74**

Termos e Condições

As imagens nesta cotação podem não corresponder a 100% da configuração seleccionada.
Os preços indicados não incluem IVA.
Período de validade da cotação é 60 dias.
Os prazos indicados começarão apartir da recepção e confirmação da encomenda.
Os prazos indicados correspondem à saída do material do nosso armazém, em dias LABORÁVEIS.

Notas e instruções
Indique por favor o nº da cotação SMC na sua encomenda, caso exista.
Se por algum motivo não estiver satisfeito com algum produto ou serviço, por favor contacte-nos através da SMC mais próxima, do seu contacto habitual, do número de telefone (+351) 226 166 570 ou ainda por email: postpt@smc.smces.es."

SMC España (Sucursal), S.A.
Rua Eng. Ferreira Dias, 452
Tel: (22) 616 65 70
Fax: (22) 616 65 89
email: apoioclientept@smc.smces.es

www.smc.eu

7.1.3 Cylinders festo + accessories

Bras, Roberto <roberto.bras@festo.com>
Tue 5/26/2020 11:28 AM
Inbox

Bom dia,

segue a info:

Cylinders					
Description	Ordernr	Component code	#	Price/unit	Total Price
up/down cylinder	536296	ADN-40-50-A-P-A	2	75,08	150,16

Acessoires					
Description	Ordernr	Component code	#	Price/unit	Total Price
Proximity sensor up/down cylinder	574334	SMT-8M-A-PS-24V-E-0,3-M8D	4	11,26	45,04
flexible coupling	6140	FK-M10x1_25	2	10,9	21,8

Cumprimentos / best regards / Saludos ,

Roberto Brás
Industry Sales ELA -ESPT
Roberto.bras@festo.com

Telem. (+351 967 007 465)

https://www.festo.com/cms/pt_pt/9511.htm

7.1.4 Linear guide + bearing

From: planofavorito@gmail.com
To: mario.cardoso@ficosa.com
Date: 13/06/2020 06:55
Subject: Orçamento

Bom dia Eng.

A ref. HGW15CA1R630ZAC corresponde a um conjunto carro + régua c/ 630mm, portanto o orçamento solicitado é o seguinte :

Carro linear Hiwin ref. HGW15CCZOH - 68,58€ / Un
Total 4 unidades - 274,32€

Régua linear Hiwin ref. HGR1570HM C/ 630mm - 66,78€ / Un
Total 4 unidades - 267,12€

Rolamento linear Ina KH2030B - 15,33€ / Un
Total 16 unidades - 245,28€

Cumprimentos

Mário Freitas

Sem vírus. www.avast.com

7.1.5 Caterpillar

PLANO FAVORITO, Lda.

Plano Favorito, Lda.
Rua da Madeira, 57 Vermoim
4470-327 Maia
Capital Social: € 500.00
Matriculada na C.R.C. da Maia nº 510355340
Contribuinte nº 510355340

planofavorito@gmail.com

Software PHC - XFW1-Processado por programa certificado nº 0006/AT (20170522)-Este documento não serve de fatura

Orçamento Nº 200001

TRIPLICADO

FICO CABLES - FÁBRICA DE ACESSÓRIOS E EQUIP. IND., LDA

RUA DO CAVACO, 115

VERMOIM
4470-263 MAIA

COD. FORNECEDOR - 26634

Pagamento: 60 Dias Data: 2020-05-29 V/ Nº de Contribuinte: 500423261 Nº de Cliente: 1

Designação	Un.	Quantidade	Pr.Unitário	Desc.	IVA	Total
CAT. REF. 300A025060_A300A025KM_500_01 TERMINAIS METÁLICOS	UN	1,000	43,40		23,0	43,40

Os Artigos / Serviços Prestados foram colocados à disposição do cliente em: 29.05.2020 Página 1 de 1
PEDIDO : ENG. MÁRIO JORGE

Taxa	Base de Incidência	Valor do I.V.A.
%		
23,00 %	43,40	9,98
6,00 %		
13,00 %		
	43,40	**9,98**

Total Ilíquido	**43,40**
Desconto Comercial	
Desconto Financeiro %	
Base de Incidência de I.V.A.	**43,40**
Total de I.V.A.	**9,98**
TOTAL DO DOCUMENTO €	**53,38**

Documento Processado por Computador
Local de Carga: N/ Instalações Hora: 11:17:04
Local de Descarga: Morada do Cliente Viatura:

IBAN: PT50 0010 0000 48618610001 53 * Banco: BPI

7.1.6 Bolts, washers, etc.

ROLPEDRA
Produtos de Manutenção Industrial

Orçamento (Cliente)
Original
Número ORC 20/1784 **Data** 2020-06-17
Pág. 1 / 2

ROLAMENTOS PONTE DA PEDRA, LDA
Tva. Alegria, 100
Maia
4475-310 Maia
Contribuinte: 502005254
Capital Social (Euro): 39 903,84
Cons.Reg.Com.: Maia com o n.º 1026
Telefone: +351 229600804
Fax:+351 229600806
Email: info@rolpedra.pt
Site: http://www.rolpedra.pt/

FICO-CABLES, LDA.

RUA DO CAVACO, 115
VERMOIM
MAIA

4470-263 MAIA

Número de Identificação Bancária
IBAN: PT50 0035 0206 00012716930 32 **IBAN:** PT50 0018 0003 10203040020 71 **IBAN:** PT50 0033 0000 00002155244 05

Cliente	Contribuinte	Referência	Vendedor	Expedição	Cond. Pagamento	Vencimento
01030	500423261	Email	01	PORTES PAGOS	Sessenta Dias	2020-06-17

Descrição	Qtd.	Preço	Desc.	IVA	Valor
PARAF.C/C UMBRAKO DIN912-12.9 M4X16	44,000	0,0250	0	23	1,10
PARAF.C/C UMBRAKO DIN912-12.9 M4X20	24,000	0,0280	0	23	0,67
PARAF.C/C UMBRAKO DIN912-12.9 M4X25	12,000	0,0320	0	23	0,38
PARAF.C/C UMBRAKO DIN912-12.9 M5X10	8,000	0,0320	0	23	0,26
PARAF.C/C UMBRAKO DIN912-12.9 M5X12	8,000	0,0298	0	23	0,24
PARAF.C/C UMBRAKO DIN912-12.9 M5X16	28,000	0,0260	0	23	0,73
PARAF.C/C UMBRAKO DIN912-12.9 M5X50	24,000	0,0561	0	23	1,35
ISO 4015 não conseguimos fornecer, segue alternativa:					
PARAF.SEXT.DIN 931 8.8 M8X30 ZN	8,000	0,0542	0	23	0,43
PARAF.SEXT.DIN 931 8.8 M10X50 ZN	8,000	0,1030	0	23	0,82
PARAF.SEXT.DIN 931 8.8 M10X60 ZN	12,000	0,1070	0	23	1,28
PARAF.SEXT.DIN 558 4.8 M12X30 ZN	24,000	0,0750	0	23	1,80
PARAF.SEXT.DIN 558 4.8 M12X60 ZN	24,000	0,1190	0	23	2,86
ISO 10669 e 10673 não conseguimos fornecer, segue alternativa:					
DIN 125-A M12 ZN - ANILHA PLANA	8,000	0,0155	0	23	0,12
a Transportar					12,04

EXPEDIÇÃO

- Os preços constantes são para os materiais nas N/ INSTALAÇÕES, salvo referência em contrário.
- Quando indicados, os custos de transporte são aproximados, podendo sofrer variação de modo a garantir um bom acondicionamento dos materiais ou devido a alterações no peso final.
- O cliente reserva-se ao direito de escolher o seu próprio modo de transporte, ficando responsável pela sua expedição, devendo informar a Rolpedra da sua intenção no acto da confirmação da encomenda.

INFORMAÇÕES COMPLEMENTARES

- Validade da Proposta: 15 dias.
- Os prazos de entrega são meramente indicativos e referem-se ao momento da execução do orçamento e são dados segundo indicação dos nossos fornecedores. Devido às transações constantes, podem variar entre o momento da consulta e confirmação da encomenda, não podendo ser imputada responsabilidade a Rolamentos Ponte da Pedra.
- Os preços de tabela ou indicados nas N/ propostas, podem, eventualmente ser alterados sem aviso prévio, desde que haja alterações de custo na origem ou no transporte.
- Os preços indicados nas N/ propostas, quando incluirem várias posições, são para a TOTALIDADE DA ENCOMENDA, podendo existir variação de preço no caso de não adjudicação da sua totalidade.
- Quando não é explicitamente comunicado pelo cliente o meio de transporte pretendido, entede-se como aceite o envia pela transportadora, acrescido dos devidos encargos.
- Devoluções serão aceites mediante acordo prévio até 15 dias úteis após a data do documento de transporte. Serão cobrados até 30% do valor de mercadoria, para despesas indexadas ao acto da devolução, tais como transporte, documentação, análise do bom estado e rearmazenamento dos materiais, salvo acordo mútuo.
- Não serão aceites devoluções de materiais que tenham sido maquinados, modificados, cortados, especificamente requisitados ou utilizados pelo cliente.
- Todos os artigos estão sujeitos a venda prévia, antes da confirmação da encomenda.

ROLPEDRA
Produtos de Manutenção Industrial

ROLAMENTOS PONTE DA PEDRA, LDA
Tva. Alegria, 100
Maia
4475-310 Maia
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Orçamento (Cliente)
Original
Número ORC 20/1784 **Data** 2020-06-17

Pág. 2 / 2

FICO-CABLES, LDA.

RUA DO CAVACO, 115
VERMOIM
MAIA

4470-263 MAIA

Número de Identificação Bancária

IBAN: PT50 0035 0206 00012716930 32 **IBAN:** PT50 0018 0003 10203040020 71 **IBAN:** PT50 0033 0000 00002155244 05

Cliente	Contribuinte	Referência	Vendedor	Expedição	Cond. Pagamento	Vencimento
01030	500423261	Email	01	PORTES PAGOS	Sessenta Dias	2020-06-17

Descrição	Qtd.	Preço	Desc.	IVA	Valor
Transporte					12,04
DIN 125-A M8 ZN - ANILHA PLANA	48,000	0,0042	0	23	0,20
FEMEA AUTOBLOCANTE DIN 982 M5	4,000	0,0150	0	23	0,06
FEMEA AUTOBLOCANTE DIN 982 M8	8,000	0,0240	0	23	0,19
FEMEA AUTOBLOCANTE DIN 982 M10	24,000	0,0580	0	23	1,39
FEMEA AUTOBLOCANTE DIN 982 M12	48,000	0,0730	0	23	3,50
TUBO QUADRADO AÇO 40X40X4	33,000	5,6700	0	23	187,11

Total 204,49

Subtotal	204,49
Descontos	0
Base Incidência	204,49
Total IVA	47,03
Total a Pagar (EUR)	**251,52**

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Este documento não constitui documento de transporte, nos termos do Decreto-Lei n.º 147/2003
Natureza: Orçamento
Emitido por programa certificado nº 2649/AT - Sage

EXPEDIÇÃO

- Os preços constantes são para os materiais nas N/ INSTALAÇÕES, salvo referência em contrário.
- Quando indicados, os custos de transporte são aproximados, podendo sofrer variação de modo a garantir um bom acondicionamento dos materiais ou devido a alterações no peso final.
- O cliente reserva-se ao direito de escolher o seu próprio modo de transporte, ficando responsável pela sua expedição, devendo informar a Rolpedra da sua intenção no acto da confirmação da encomenda.

INFORMAÇÕES COMPLEMENTARES

- Validade da Proposta: 15 dias.
- Os prazos de entrega são meramente indicativos e referem-se ao momento da execução do orçamento e são dados segundo indicação dos nossos fornecedores. Devido às transações constantes, podem variar entre o momento da consulta e confirmação da encomenda, não podendo ser imputada responsabilidade a Rolamentos Ponte da Pedra.
- Os preços de tabela ou indicados nas N/ propostas, podem, eventualmente ser alterados sem aviso prévio, desde que haja alterações de custo na origem ou no transporte.
- Os preços indicados nas N/ propostas, quando incluirem várias posições, são para a TOTALIDADE DA ENCOMENDA, podendo existir variação de preço no caso de não adjudicação da sua totalidade.
- Quando não é explicitamente comunicado pelo cliente o meio de transporte pretendido, entede-se como aceite o envia pela transportadora, acrescido dos devidos encargos.
- Devoluções serão aceites mediante acordo prévio até 15 dias úteis após a data do documento de transporte. Serão cobrados até 30% do valor de mercadoria, para despesas indexadas ao acto da devolução, tais como transporte, documentação, análise do bom estado e rearmazenamento dos materiais, salvo acordo mútuo.
- Não serão aceites devoluções de materiais que tenham sido maquinados, modificados, cortados, especificamente requisitados ou utilizados pelo cliente.
- Todos os artigos estão sujeitos a venda prévia, antes da confirmação da encomenda.

Rolamentos e Sistemas Lineares | Manutenção Industrial | Lubrificação | Transmissão Mecânica | Máquinas e Ferramentas
Gases Industriais e Soldadura | Componentes Industriais | Fixação e Vedação | Abrasivos | Equips. Protecção Individual

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7.2 Drawing information

7.2.1 ISO 2768

General Tolerances to DIN ISO 2768

- The latest DIN standard sheet version applies to all parts made to DIN standards.
- Variations on dimensions without tolerance values are according to "DIN ISO 2768- mk".

GENERAL TOLERANCES FOR LINEAR AND ANGULAR DIMENSIONS (DIN ISO 2768 T1)

LINEAR DIMENSIONS:

Permissible deviations in mm for ranges in nominal lengths	f (fine)	Tolerance class designation (description)		v (very coarse)
		m (medium)	c (coarse)	
0.5 up to 3	±0.05	±0.1	±0.2	-
over 3 up to 6	±0.05	±0.1	±0.3	±0.5
over 6 up to 30	±0.1	±0.2	±0.5	±1.0
over 30 up to 120	±0.15	±0.3	±0.8	±1.5
over 120 up to 400	±0.2	±0.5	±1.2	±2.5
over 400 up to 1000	±0.3	±0.8	±2.0	±4.0
over 1000 up to 2000	±0.5	±1.2	±3.0	±6.0
over 2000 up to 4000	-	±2.0	±4.0	±8.0

EXTERNAL RADIUS AND CHAMFER HEIGHTS

Permissible deviations in mm for ranges in nominal lengths	f (fine)	Tolerance class designation (description)		v (very coarse)
		m (middle)	c (coarse)	
0.5 up to 3	±0.2	±0.2	±0.4	±0.4
over 3 up to 6	±0.5	±0.5	±1.0	±1.0
over 6	±1.0	±1.0	±2.0	±2.0

Permissible deviations in degrees and minutes for ranges in nominal lengths	f (fine)	Tolerance class designation (description)		v (very coarse)
		m (middle)	c (coarse)	
up to 10	±1º	±1º	±1º30'	±3º
over 10 up to 50	±0º30'	±0º30'	±1º	±2º
over 50 up to 120	±0º20'	±0º20'	±0º30'	±1º
over 120 up to 400	±0º10'	±0º10'	±0º15'	±0º30'
over 400	±0º5'	±0º5'	±0º10'	±0º20'

GENERAL TOLERANCES FOR FORM AND POSITION (DIN ISO 2768 T2)

STRAIGHTNESS AND FLATNESS

Ranges in nominal lengths in mm	Tolerance class		
	H	K	L
up to 10	0.02	0.05	0.1
over 10 up to 30	0.05	0.1	0.2
over 30 up to 100	0.1	0.2	0.4
over 100 up to 300	0.2	0.4	0.8
over 300 up to 1000	0.3	0.6	1.2
over 1000 up to 3000	0.4	0.8	1.6

PERPENDICULARITY

Ranges in nominal lengths in mm	Tolerance class		
	H	K	L
up to 100	0.2	0.4	0.6
over 100 up to 300	0.3	0.6	1
over 300 up to 1000	0.4	0.8	1.5
over 1000 up to 3000	0.5	0.8	2

SYMMETRY

Ranges in nominal lengths in mm	Tolerance class		
	H	K	L
up to 100	0.5	0.6	0.6
over 100 up to 300	0.5	0.6	1
over 300 up to 1000	0.5	0.8	1.5
over 1000 up to 3000	0.5	1	2

Tolerance class		
H	K	L
0.1	0.2	0.5

7.2.2 ISO 13920

DEUTSCHE NORM **November 1996**

Schweißen
Allgemeintoleranzen für Schweißkonstruktionen
Längen- und Winkelmaße Form und Lage
(ISO 13920 : 1996) Deutsche Fassung EN ISO 13920 : 1996

DIN EN ISO 13920

ICS 25.160.00

Deskriptoren: Schweißkonstruktion, Allgemeintoleranz, Längenmaß, Winkelmaß, Toleranzklasse

Ersatz für DIN 8570-1: 1987-10 und DIN 8570-3: 1987-10

Welding — General tolerances for welded constructions — Dimensions for lengths and angles, Shape and position (ISO 13920 : 1996); German version EN ISO 13920 : 1996

Soudage — Tolérances générales relatives aux constructions soudées — Dimensions des longueurs et angles, Formes et positions (ISO 13920 : 1996); Version allemande EN ISO 13920 : 1996

Die Europäische Norm EN ISO 13920 : 1996 hat den Status einer Deutschen Norm.

Nationales Vorwort

Die Europäische Norm EN ISO 13920: 1996 wurde im Technischen Komitee CEN/TC 121 "Schweißen" vom Unterkomitee SC 4 "Qualitätsmanagement für das Schweißen" erarbeitet. Das zuständige deutsche Normungsgremium ist der Arbeitsausschuß AA 4.5 "Zulässige Abweichungen und Toleranzen" gemeinsam mit AA 4.1 "Grundlagen der Qualitätssicherung beim Schweißen" im Normenausschuß Schweißtechnik (NAS).

Die Norm enthält ohne Einschränkung der Anwendungsgebiete Allgemeintoleranzen für Längen- und Winkelmaße sowie für Form und Lage bei Schweißkonstruktionen. Diese Norm ist für geschweißte Konstruktionen anzuwenden, es sei denn, daß hierfür besondere Regelwerke mit abweichenden Anforderungen bestehen.

Die Festlegung von Toleranzklassen nimmt Rücksicht auf die unterschiedlichen Anforderungen in den verschiedenen Anwendungsgebieten, ihnen liegen jedoch die werkstattüblichen Genauigkeiten zugrunde. Dennoch ist zur Einhaltung der Toleranzklasse unterschiedlicher Aufwand erforderlich.

Der Aufwand wächst mit der jeweils höheren Toleranzklasse. Anforderungen und Toleranzklasse sind deshalb aufeinander abzustimmen.

Es können in einer Zeichnung für die Längen- und Winkeltoleranzen nach Tabelle 1 und 2 und für die Form- und Lagetoleranzen nach Tabelle 3 verschiedene Toleranzklassen gewählt werden. Die Norm enthält für diese Fälle Bezeichnungsbeispiele (siehe Abschnitt 5).

Die Toleranzen brauchen nicht zu jedem Nennmaß angegeben zu werden, es genügt ein allgemeiner Hinweis auf die Toleranzklasse in den Zeichnungen und/oder sonstigen Unterlagen, z. B. Lieferbedingungen, Arbeitsunterlagen.

Für die Feststellung der Winkelabweichung wurden die beiden Maßsysteme Grad und Minuten oder gerechnet und gerundet in Millimeter gleichberechtigt nebeneinander zugelassen, um die Anwendung der jeweils günstigeren und zweckmäßigeren Meßmethode sowie den Einsatz vorhandener Meßinstrumente zu ermöglichen.

Bei Angabe von Winkeln kann die Lage des Schnittpunktes der beiden Schenkel so wichtig sein, daß sie als "Bezugspunkt" besonders gekennzeichnet und bemaßt werden sollte (siehe Bilder 1 bis 5).

Für die im Abschnitt 2 zitierten Internationalen Normen wird im folgenden auf die entsprechenden Deutschen Normen hingewiesen:

ISO/DIS 463	entspricht E DIN EN ISO 463
prEN ISO 1101	entspricht E DIN ISO 1101
ISO 3599	entspricht E DIN EN 13385
ISO 6906	entspricht E DIN EN 13385
ISO 8015	entspricht DIN ISO 8015

Fortsetzung Seite 2
und 5 Seiten EN

Normenausschuß Schweißtechnik (NAS) im DIN Deutsches Institut für Normung e.V.
Normenausschuß Länge und Gestalt (NLG) im DIN
Normenausschuß Schienenfahrzeuge (FSF) im DIN

Ref. Nr. DIN EN ISO 13920 : 1996-11
Preisgr. 07 *Vertr.-Nr. 2307*

Seite 2
DIN EN ISO 13920 : 1996-11

Änderungen

Gegenüber DIN 8570-1 : 1987-10 und DIN 8570-3 : 1987-10 wurden folgende Änderungen vorgenommen:

— Anwendungsbereiche der Teile 1 und 3 zusammengefaßt.

— Toleranzklasse Z für besondere Fälle, z.B. bei dünnen Blechen in Triebwerksbau, ist entfallen.

Frühere Ausgaben

DIN 8570-1: 1971-04, 1974-10, 1987-10
DIN 8570-3: 1974-10, 1987-10
DIN 25029: 1962-04

Nationaler Anhang NA (informativ)

Literaturhinweise

E DIN EN 13385
Geometrische Produktspezifikationen (GPS) — Längenmeßgeräte: Meßschieber und Tiefenmeßschieber — Bauformen und meßtechnische Anforderungen (ISO/DIS 13385 : 1996); Deutsche Fassung prEN ISO 13385 : 1996

E DIN EN ISO 463
Geometrische Produktspezifikationen (GPS) — Längenmeßgeräte: Meßuhren — Bauformen und meßtechnische Anforderungen (ISO/DIS 463 : 1996); Deutsche Fassung prEN ISO 463 : 1996

E DIN ISO 1101
Technische Zeichnungen — Form- und Lagetolerierung — Tolerierung von Form, Richtung, Ort und Lauf — Allgemeines, Definitionen, Symbole, Zeichnungseintragungen (ISO/DIS 1101 : 1995)

DIN ISO 8015 : 1986
Technische Zeichnungen — Tolerierungsgrundsatz; Identisch mit ISO 8015 : 1985

EUROPÄISCHE NORM
EUROPEAN STANDARD
NORME EUROPÉENNE

EN ISO 13920

August 1996

ICS 25.160.00

Deskriptoren: Schweißen, Schweißkonstruktion, Form, Lage, Maße, Länge, Winkel, Maßtoleranzen, Winkeltoleranzen, Prüfungen

Deutsche Fassung

Schweißen

Allgemeintoleranzen für Schweißkonstruktionen

Längen- und Winkelmaße Form und Lage
(ISO 13920: 1996)

Welding — General tolerances for welded constructions — Dimensions for lengths and angles, Shape and position (ISO 13920 : 1996)

Soudage — Tolérances générales relatives aux constructions soudées — Dimensions des longueurs et angles, Formes et positions (ISO 13920 : 1996)

Diese Europäische Norm wurde von CEN am 1996-06-20 angenommen.

Die CEN-Mitglieder sind gehalten, die CEN/CENELEC-Geschäftsordnung zu erfüllen, in der die Bedingungen festgelegt sind, unter denen dieser Europäischen Norm ohne jede Änderung der Status einer nationalen Norm zu geben ist.

Auf dem letzten Stand befindliche Listen dieser nationalen Normen mit ihren bibliographischen Angaben sind beim Zentralsekretariat oder bei jedem CEN-Mitglied auf Anfrage erhältlich.

Diese Europäische Norm besteht in drei offiziellen Fassungen (Deutsch, Englisch, Französisch). Eine Fassung in einer anderen Sprache, die von einem CEN-Mitglied in eigener Verantwortung durch Übersetzung in seine Landessprache gemacht und dem Zentralsekretariat mitgeteilt worden ist, hat den gleichen Status wie die offiziellen Fassungen.

CEN-Mitglieder sind die nationalen Normungsinstitute von Belgien, Dänemark, Deutschland, Finnland, Frankreich, Griechenland, Irland, Island, Italien, Luxemburg, Niederlande, Norwegen, Österreich, Portugal, Schweden, Schweiz, Spanien und dem Vereinigten Königreich.

CEN

EUROPÄISCHES KOMITEE FÜR NORMUNG
European Committee for Standardization
Comité Européen de Normalisation

Zentralsekretariat: rue de Stassart 36, B-1050 Brüssel

Ref. Nr. EN ISO 13920 : 1996 D

Seite 2
EN ISO 13920 : 1996

Inhalt

Vorwort

Der Text der EN ISO 13920 : 1996 wurde vom Technischen Komitee CEN/TC 121 "Schweißen", dessen Sekretariat vom DS betreut wird, in Zusammenarbeit mit dem Technischen Komitee ISO/TC 44 "Schweißen und verwandte Verfahren" erarbeitet.

Diese Europäische Norm muß den Status einer nationalen Norm erhalten, entweder durch Veröffentlichung eines identischen Textes oder durch Anerkennung bis Februar 1997, und etwaige entgegenstehende nationale Normen müssen bis Februar 1997 zurückgezogen werden.

Entsprechend der CEN/CENELEC-Geschäftsordnung sind die nationalen Normungsinstitute der folgenden Länder gehalten, diese Europäische Norm zu übernehmen:

Belgien, Dänemark, Deutschland, Finnland, Frankreich, Griechenland, Irland, Island, Italien, Luxemburg, Niederlande, Norwegen, Österreich, Portugal, Schweden, Schweiz, Spanien und das Vereinigte Königreich.

1 Anwendungsbereich

Diese Europäische Norm legt Allgemeintoleranzen für Längen- und Winkelmaße sowie für Form und Lage an Schweißkonstruktionen in vier Toleranzklassen fest, die auf werkstattüblichen Genauigkeiten basieren. Das Hauptkriterium für die Auswahl einer bestimmten Toleranzklasse sollte sich auf die einzuhaltenden funktionellen Anforderungen beziehen.

Die anzuwendenden Toleranzen/Grenzabmaße sind in jedem Fall diejenigen, die in der Zeichnung angegeben sind. Statt einzelne Toleranzen/Grenzabmaße festzulegen, können die Toleranzklassen nach dieser Norm angewendet werden. Allgemeintoleranzen für Längen- und Winkelmaße sowie Form und Lage, wie sie in dieser Norm festgelegt sind, gelten für Schweißteile, Schweißgruppen, geschweißte Bauteile usw.

Besondere Bedingungen können für komplexe Bauteile notwendig sein.

Die Festlegungen in dieser Norm basieren auf dem Unabhängigkeitsprinzip, das in ISO 8015 festgelegt ist. Danach sind die Maß-Grenzabweichungen und geometrischen Toleranzen unabhängig voneinander anzuwenden.

Fertigungsunterlagen, die Längen- oder Winkelmaße oder Angaben für Form und Lage ohne einzeln eingetragene Toleranzen/Grenzabmaße enthalten, sind als unvollständig anzusehen, wenn sie keinen oder nur einen unvollständigen Bezug auf die Allgemeintoleranzen haben. Dieses ist nicht für zeitweilige Zwischenmaße anzuwenden.

2 Normative Verweisungen

Diese Europäische Norm enthält durch datierte oder undatierte Verweisungen Festlegungen aus anderen Publikationen. Diese normativen Verweisungen sind an den jeweiligen Stellen im Text zitiert, und die Publikationen sind nachstehend aufgeführt. Bei datierten Verweisungen gehören spätere Änderungen oder Überarbeitungen dieser Publikationen nur zu dieser Europäischen Norm, falls sie durch Änderung oder Überarbeitung eingearbeitet sind. Bei undatierten Verweisungen gilt die letzte Ausgabe der in Bezug genommenen Publikation.

ISO/DIS 463
de: Geometrische Produktspezifikation (GPS) — Längenmeßgeräte: Meßuhren — Bauformen und meßtechnische Anforderungen
en: Geometrical product specifications (GPS) – Dimensional measuring instruments: Dial gauges — Design and metrological requirements

prEN ISO 1101
de: Technische Zeichnungen — Form- und Lagetolerierung — Form-, Richtungs-, Orts- und Lauftoleranzen — Allgemeines, Definitionen, Symbole, Zeichnungseintragungen (ISO/DIS 1101 : 1995)
en: Technical drawings — Tolerances of form, orientation, location and run-out — Generalities, definitions, Symbols, indications on drawings (ISO/DIS 1101 : 1995)

Tabelle 1: Grenzabmaße für Längenmaße

Toleranz-klasse	Nennmaßbereich l (in mm)										
	2 bis 30	über 30 bis 120	über 120 bis 400	über 400 bis 1 000	über 1 000 bis 2 000	über 2 000 bis 4 000	über 4 000 bis 8 000	über 8 000 bis 12 000	über 12 000 bis 16 000	über 16 000 bis 2 0000	über 2 0000
	Grenzabmaße t (in mm)										
A	± 1	± 1	± 1	± 2	± 3	± 4	± 5	± 6	± 7	± 8	± 9
B		± 2	± 2	± 3	± 4	± 6	± 8	± 10	± 12	± 14	± 16
C		± 3	± 4	± 6	± 8	± 11	± 14	± 18	± 21	± 24	± 27
D		± 4	± 7	± 9	± 12	± 16	± 21	± 27	± 32	± 36	± 40

ISO 3599
de: Meßschieber mit Noniusteilung bis 0,1 und 0,05 mm
en: Vernier callipers reading to 0,1 and 0,05 mm

ISO 6906
de: Meßschieber mit Noniusteilung bis 0,02 mm
en: Vernier callipers reading to 0,02 mm

ISO 8015
de: Technische Zeichnungen — Tolerierungsgrundsatz
en: Technical drawings — Fundamental tolerancing principle

3 Definitionen

Für die Anwendung dieser Norm gelten die Definitionen von prEN ISO 1101.

4 Allgemeintoleranzen

4.1 Grenzabmaße für Längenmaße

Siehe Tabelle 1.

4.2 Grenzabmaße für Winkelmaße

Die Länge des kürzeren Winkelschenkels ist zur Bestimmung der Grenzabmaße nach Tabelle 2 anzuwenden. Es kann auch vereinbart werden, die Schenkellänge bis zu einem festgelegten Bezugspunkt auszudehnen. In diesem Fall ist der Bezugspunkt auf der Zeichnung anzugeben.

Siehe Tabelle 2 für die entsprechenden Grenzabmaße.

Die Bilder 1 bis 5 zeigen Beispiele, wie der kürzere Winkelschenkel, l, dargestellt wird.

4.3 Geradheits-, Ebenheits- und Parallelitätstoleranzen

Die Geradheits-, Ebenheits- und Parallelitätstoleranzen sind in der nachfolgenden Tabelle 3 sowohl für die Gesamtabmessung eines Schweißteils, einer Schweißgruppe oder eines geschweißten Bauteils als auch für sonstige bemaßte Teile festgelegt.

Andere Toleranzen für Form und Lage, z. B. Koaxialitäts-, Symmetrietoleranzen, sind nicht festgelegt. Wenn derartige Toleranzen aus Funktionsgründen gefordert werden, sind sie auf den Zeichnungen so anzugeben, wie es in prEN ISO 1101 festgelegt ist.

Tabelle 2: Grenzabmaße für Winkelmaße

Toleranz-klasse	Nennmaßbereich l (in mm) (Länge oder kürzerer Schenkel)		
	bis 400	über 400 bis 1 000	über 1 000
	Grenzabmaße $\Delta\alpha$ (in Grad und Minuten)		
A	± 20′	± 15′	± 10′
B	± 45′	± 30′	± 20′
C	± 1°	± 45′	± 30′
D	± 1° 30′	± 1° 15′	± 1°
	Gerechnete und gerundete Grenzabmaße t (in mm/m[1]))		
A	± 6	± 4,5	± 3
B	± 13	± 9	± 6
C	± 18	± 13	± 9
D	± 26	± 22	± 18

[1]) Die Angabe in mm/m entspricht dem Tangenswert der Grenzabmaße. Sie ist mit der Länge in Meter des kürzeren Schenkels zu multiplizieren.

5 Zeichnungsangaben

Die Bezeichnung der gewählten Toleranzklasse ist — wie es in den Tabellen 1 und 2 (z. B. EN ISO 13920-B) oder in ihrer Kombination mit einer Toleranzklasse nach Tabelle 3 (z. B. EN ISO 13920-BE) festgelegt ist — in das entsprechende Zeichnungsfeld einzutragen.

Seite 4
EN ISO 13920 : 1996

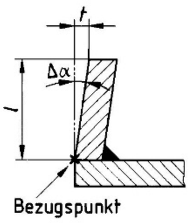
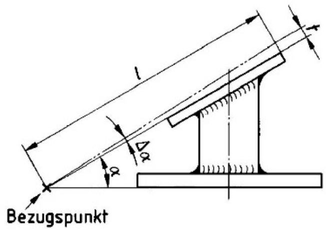


Bild 1



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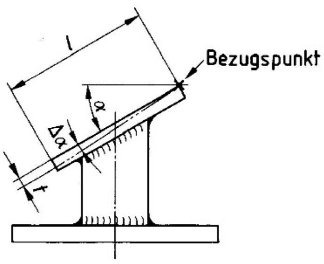

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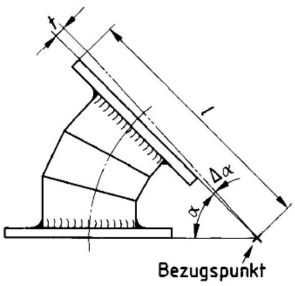


Bild 4

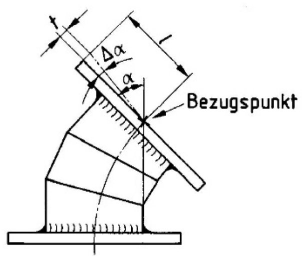


Bild 5

Tabelle 3: Geradheits-, Ebenheits- und Parallelitätstoleranzen

Toleranz-klasse	Nennmaßbereich *l* (in mm) (bezieht sich auf die längere Seite der Oberfläche)									
	über 30 bis 120	über 120 bis 400	über 400 bis 1 000	über 1 000 bis 2 000	über 2 000 bis 4 000	über 4 000 bis 8 000	über 8 000 bis 12 000	über 12 000 bis 16 000	über 16 000 bis 2 0000	über 2 0000
	Toleranzen *t* (in mm)									
E	0,5	1	1,5	2	3	4	5	6	7	8
F	1	1,5	3	4,5	6	8	10	12	14	16
G	1,5	3	5,5	9	11	16	20	22	25	25
H	2,5	5	9	14	18	26	32	36	40	40

6 Prüfung

6.1 Allgemeines

Die verwendeten Prüf- und Meßgeräte müssen für den vorgesehenen Zweck geeignet und genau sein.

- Strichmaßstab;
- Meßbänder;
- Lineale;
- Meßwinkel;
- Meßschieber (nach ISO 3599 und ISO 6906);
- Meßuhren (nach ISO/DIS 463).

Andere Prüf- und Meßgeräte können nach Vereinbarung benutzt werden.

Die Meßergebnisse können beeinflußt werden, wenn sie bei ungewöhnlichen Temperaturen oder Witterungsverhältnissen ermittelt werden, z. B. Großbauteile bei starker Sonneneinstrahlung.

Das Istmaß eines Winkels wird durch Anwendung von geeigneten Meßwerkzeugen ermittelt. Sie werden tangential an das Schweißteil, jedoch außerhalb der unmittelbar beeinflußten Zone, angelegt. Die Abweichung wird aus der Differenz zwischen dem Nennmaß und dem Istmaß bestimmt. Die Winkelabweichungen können in Grad und Minuten oder in Millimeter ermittelt werden.

Seite 5
EN ISO 13920 : 1996

6.2 Geradheit

Die Kante des Schweißteils und das Richtlineal werden so zueinander ausgerichtet, daß der größte Abstand zwischen dem Richtlineal und der tatsächlichen Oberfläche sein Mindestwert ist. Die Abstände zwischen der Kante und dem Richtlineal werden gemessen (siehe Beispiel Bild 6).

6.3 Ebenheit

Die tatsächliche Oberfläche des Schweißteils und die Meßebene werden so zueinander ausgerichtet, daß der größte Abstand zwischen der Meßebene und der tatsächlichen Oberfläche sein Mindestwert ist. Dies kann z. B. durch optische Geräte, Schlauchwasserwaagen, Spanndrähte, Spann- und Meßplatten und Maschinenbetten geschehen.

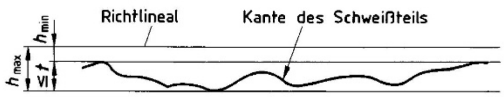
Die Abstände zwischen der tatsächlichen Oberfläche und der Meßebene sind zu messen (siehe Beispiel Bild 7).

6.4 Parallelität

Die Bezugsfläche ist parallel zur Bezugsebene auszurichten. Parallel zur Bezugsebene ist eine Meßebene außerhalb des Schweißteils unter Verwendung der in 6.3 genannten Meßgeräte zu schaffen. Die Abstände zwischen der tatsächlichen Oberfläche und der Meßebene sind zu messen (siehe Beispiel Bild 8).

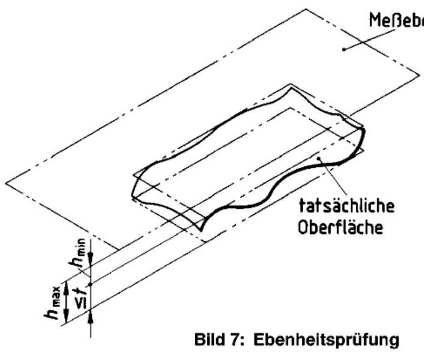
7 Mangelnde Übereinstimmung

Eine Entscheidung über die Verwendbarkeit von Bauteilen, die nicht mit dieser Norm übereinstimmen, kann auf der Grundlage der Eignung für ihren vorgesehenen Zweck getroffen werden.



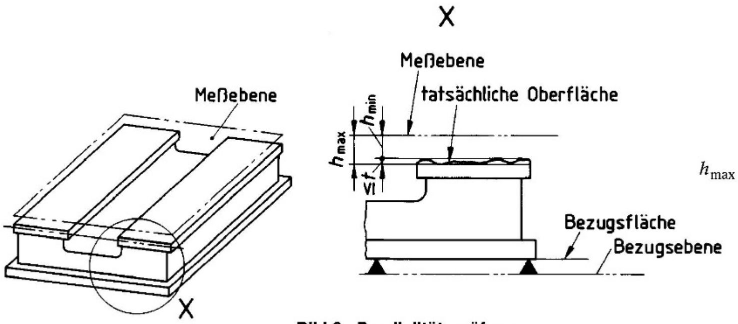
$h_{max} - h_{min} \leq t$

Bild 6: Geradheitsprüfung



$h_{max} - h_{min} \leq t$

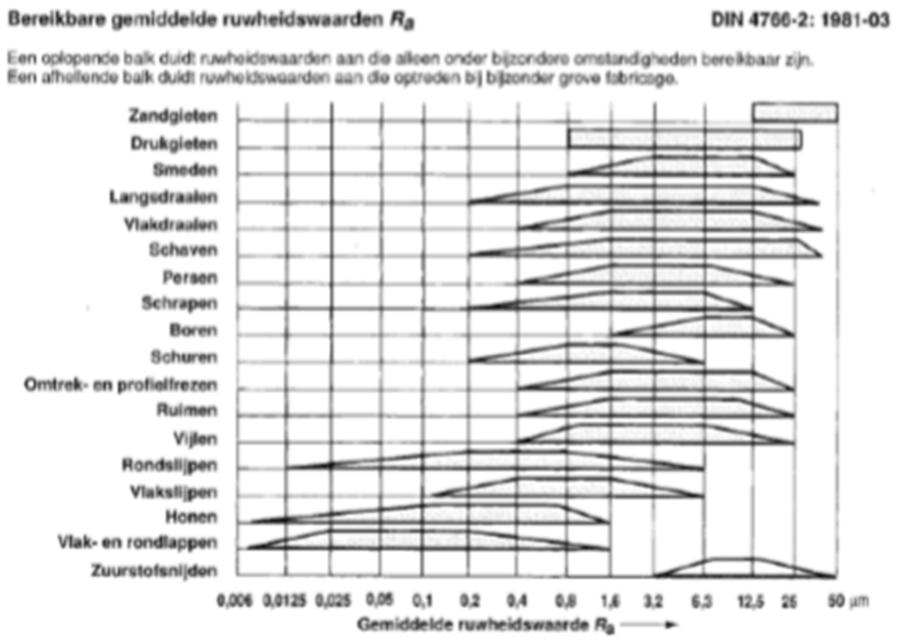
Bild 7: Ebenheitsprüfung



$h_{max} - h_{min} \leq t$

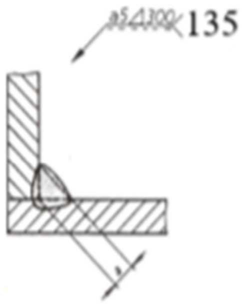
Bild 8: Parallelitätsprüfung

7.2.3 Surface roughness



7.2.4 Throat section welds

Bematen van lasnaden



(lasprocédé)

Maten voor dwarsdoorsnede:

komen **links** van het vormsymbool.

Andere afmetingen:

komen **rechts** van het vormsymbool

a: Keeldoorsnede (Europese bemating)

(a= 0.6 à 0.8 x plaatdikte)

7.3 Calculation of the total cost of the manipulator system

7.3.1 Cost of the sub-assemblies

We can check the price of the different assemblies in the following sections separately. In the end, these are summed up to calculate the total cost of the project.

7.3.1.1 Gripper system

Designed components

Table 36: Price calculation of the designed components of the gripper system.

Description	QTY	Material cost/unit (net)	Machining cost/unit (net)	+indirect cost (20%)	+ profit yield (25%)	+ taxes (23%) =(Total/ unit)	Total
Longer_side_1	1	5,78 €	38,50 €	46,20 €	57,75 €	78,14 €	78,14 €
Longer_side_2	1	5,78 €	38,50 €	46,20 €	57,75 €	78,14 €	78,14 €
Short_side_gripping_system	1	3,69 €	16,00 €	19,20 €	24,00 €	34,06 €	34,06 €
Side_holder_scrap_gripper	2	3,69 €	19,25 €	23,10 €	28,88 €	40,05 €	80,11 €
Middle_holder_scrap_gripper	2	1,79 €	19,25 €	23,10 €	28,88 €	37,72 €	75,44 €
Vertical_side_1_gripping_system	1	3,35 €	23,50 €	28,20 €	35,25 €	47,48 €	47,48 €
Vertical_side_2_gripping_system	1	3,35 €	23,50 €	28,20 €	35,25 €	47,48 €	47,48 €
Vertical_side_3_gripping_system	1	3,35 €	23,50 €	28,20 €	35,25 €	47,48 €	47,48 €
Vertical_side_4_gripping_system	1	3,35 €	23,50 €	28,20 €	35,25 €	47,48 €	47,48 €
Span_long_sides_gripper	2	2,64 €	13,75 €	16,50 €	20,63 €	28,62 €	57,23 €

Description	QTY	Material cost/unit (net)	Machining cost/unit (net)	+indirect cost (20%)	+ profit yield (25%)	+ taxes (23%) =(Total/ unit)	Total
Mounting_plate _gripper	1	2,32 €	10,50 €	12,60 €	15,75 €	22,23 €	22,23 €
Scrap gripper	2			- €	- €	405,49 €	810,98 €
Lock_down_grip per	2	0,11 €	17,00 €	20,40 €	25,50 €	31,50 €	63,00 €
Lock_up_gripper	2	0,41 €	23,75 €	28,50 €	35,63 €	44,32 €	88,65 €
Middle_support _holder_for_gri pper	2	1,79 €	19,25 €	23,10 €	28,88 €	37,72 €	75,44 €
Fixed_distance_ plate	2	3,33 €	33,00 €	39,60 €	49,50 €	64,98 €	129,96 €
L_guidance_loc k_gripper	4	1,37 €	21,50 €	25,80 €	32,25 €	41,35 €	165,41 €
Locking_gripper	2	2,33 €	25,75 €	30,90 €	38,63 €	50,37 €	100,75 €
Cylinder_mount ing_block_lock_ gripper	2	0,42 €	27,25 €	32,70 €	40,88 €	50,79 €	101,59 €
				Total designed parts			**2151,03 €**

Table 37: Price calculation of the standard components of the gripper system.

Description	Standard	length	QTY	Price/unit	+23% taxes =(total/ unit)	Total
Socket head screw	ISO4762	M4x20	4	0,03 €	0,03 €	0,14 €
Socket head screw	ISO4762	M5x25	10	0,03 €	0,03 €	0,33 €
Socket head screw	ISO4762	M6x35	8	0,04 €	0,04 €	0,36 €
Socket head screw	ISO4762	M6x25	4	0,04 €	0,04 €	0,17 €
Socket head screw	ISO4762	M8x35	12	0,05 €	0,07 €	0,80 €
Socket head screw	ISO4762	M8x25	6	0,05 €	0,07 €	0,40 €
Socket head screw	ISO4762	M8x16	4	0,05 €	0,07 €	0,27 €
Socket head screw	ISO4762	M10x30	4	0,10 €	0,13 €	0,51 €
Plain washer	ISO10669	7.15-N	4	0,00 €	0,01 €	0,02 €
Plain washer	ISO10669	8.8-N	4	0,00 €	0,01 €	0,02 €

Description	Standard	length	QTY	Price/unit	+23% taxes =(total/unit)	Total
CDQSB20-5DM			2	19,36 €	23,81 €	47,63 €
CDQS20-CQ-M5x35L			8	0,21 €	0,26 €	2,07 €
D-M9PSAPC-595			4	11,59 €	14,26 €	57,02 €
Scrap gripper			2		51,83 €	103,65 €
			Total standard parts		**213,38 €**	

7.3.1.2 Scrap gripperesigned components

Table 38: Price calculation of the designed components of the scrap gripper.

Description	QTY	Material cost/unit (net)	Machining cost/unit (net)	+indirect cost (20%)	+ profit yield (25%)	+ taxes (23%) =(Total/unit)	Total
Height adjusting	1	0,20 €	15,75 €	18,90 €	23,63 €	29,30 €	29,30 €
Gripper	2	0,08 €	49,25 €	59,10 €	73,88 €	90,96 €	181,93 €
Extension_on_cylinder	1	0,05 €	5,75 €	6,90 €	8,63 €	10,67 €	10,67 €
Bottom_scrap_gripper	1	0,36 €	50,00 €	60,00 €	75,00 €	92,70 €	92,70 €
Top_scrap_gripper	1	0,40 €	49,00 €	58,80 €	73,50 €	90,89 €	90,89 €
				Total designed parts		**405,49 €**	

Table 39: Price calculation of the standard components of the scrap gripper.

Description	Standard	length	QTY	Price/unit	+ taxes (23%)	Total
Socket head screw	ISO4762	M5x50	4	0,06 €	0,07 €	0,28 €
Socket head screw	DIN912	M5x30	2	0,03 €	0,04 €	0,08 €
Socket head screw	ISO4762	M4x25	1	0,03 €	0,04 €	0,04 €
Socket screw flat point	DIN913	M5x12	1	0,03 €	0,04 €	0,04 €
CDQSB20-5D			1	18,56 €	22,83 €	22,83 €
Prevailing torque	ISO10511	M5-N	2	0,02 €	0,02 €	0,04 €
Prevailing torque	ISO10511	M4-N	1	0,01 €	0,01 €	0,01 €
D-M9PSAPC-595			2	11,59 €	14,26 €	28,51 €
				Total standard parts	**51,83 €**	

7.3.1.3 Lever systemdesigned components

Table 40: Price calculation of the designed components of the lever system.

Description	QTY	Material cost/unit (net)	Machining cost/unit (net)	+indirect cost (20%)	+ profit yield (25%)	+taxes (23%)=(total/unit)	Total
Vertical_support_holder_guiding_rail	2	0,68 €	25,00 €	30,00 €	37,50 €	46,96 €	93,92 €
Rod_for_block_linear_guide	2	0,02 €	10,00 €	12,00 €	15,00 €	18,47 €	36,95 €
Fixing_plate_lever_arm	1	3,86 €	24,75 €	29,70 €	37,13 €	50,41 €	50,41 €
Guiding_cylinder	3	0,89 €	8,00 €	9,60 €	12,00 €	15,85 €	47,56 €
Bearing_housing	3	2,01 €	34,50 €	41,40 €	51,75 €	66,12 €	198,37 €
Guide_and_mounting_plate_lever_system_highest	1	3,52 €	68,75 €	82,50 €	103,13 €	131,17 €	131,17 €
Guide_and_mounting_plate_lever_system_lowest	1	3,33 €	28,50 €	34,20 €	42,75 €	56,68 €	56,68 €
Guiding_block_for_linear_guide	2	0,10 €	24,75 €	29,70 €	37,13 €	45,79 €	91,57 €
Alu_block_2_lever_arm	1	2,52 €	26,25 €	31,50 €	39,38 €	51,53 €	51,53 €
Holder_guiding_rail_cylinder	2	6,49 €	38,50 €	46,20 €	57,75 €	79,02 €	158,03 €
Backplate_mounting_linear_guide	1	8,45 €	19,50 €	23,40 €	29,25 €	46,37 €	46,37 €
Lever_arm	2	10,13 €	65,50 €	78,60 €	98,25 €	133,31 €	266,61 €
St_block_holder_lever _arm	1	6,89 €	38,50 €	46,20 €	57,75 €	79,51 €	79,51 €
Al_Blok1_lever_holder	1	6,64 €	28,50 €	34,20 €	42,75 €	60,75 €	60,75 €
				Total designed parts		**2151,03 €**	

Table 41: Price calculation of the standard components of the lever system.

Description	Standard	Length	QTY	Price/unit	+23% taxes = (total/unit	Total
Socket head screw	ISO4762	M4x20	4	0,03 €	0,03 €	0,14 €
Socket head screw	ISO4762	M5x25	10	0,03 €	0,03 €	0,33 €
Socket head screw	ISO4762	M6x35	8	0,04 €	0,04 €	0,36 €
Socket head screw	ISO4762	M6x25	4	0,04 €	0,04 €	0,17 €
Socket head screw	ISO4762	M8x35	12	0,05 €	0,07 €	0,80 €
Socket head screw	ISO4762	M8x25	6	0,05 €	0,07 €	0,40 €
Socket head screw	ISO4762	M8x16	4	0,05 €	0,07 €	0,27 €
Socket head screw	ISO4762	M10x30	4	0,10 €	0,13 €	0,51 €
Plain washer	ISO10669	7.15-N	4	0,00 €	0,01 €	0,02 €
Plain washer	ISO10669	8.8-N	4	0,00 €	0,01 €	0,02 €
CDQSB20-5DM			2	19,36 €	23,81 €	47,63 €
CDQS20-CQ-M5x35L			8	0,21 €	0,26 €	2,07 €
D-M9PSAPC-595			4	11,59 €	14,26 €	57,02 €
Scrap gripper			2		51,83 €	103,65 €
			Total standard parts		**213,38 €**	

7.3.1.4 assembly gripper+lever+energychain

Designed components

Table 42:Price calculation of the designed components of the connection between energy chain, lever system and gripper system.

Description	QTY	Material cost/unit (net)	Machining cost/unit (net)	+indirect cost (20%)	+ profit yield (25%)	+taxes (23%)=(total/unit)	Total
L-bracket energy chain	1	0,11 €	4,50 €	5,40 €	6,75 €	8,44 €	**8,44 €**

Standard components

Table 43: Price calculation of the standard components of the connection between energy chain, lever system and gripper system.

Description	Standard	Length	QTY	Price/unit	+ taxes(23%) =Total/unit	Total
Hex bolt grade b	ISO4015	M10x50	4	0,10 €	0,13 €	0,51 €
Hex bolt grade b	ISO4015	M8x30	4	0,05 €	0,07 €	0,27 €
Torque nut	ISO7040	M8	4	0,02 €	0,03 €	0,12 €
Torque nut	ISO7040	M10	4	0,06 €	0,07 €	0,29 €
Plain washer	ISO10673	11-N	4	0,02 €	0,02 €	0,08 €
Plain washer	ISO10669	8.8-N	4	0,00 €	0,01 €	0,02 €
300A025060_A300A025KM_500_01			1	53,38 €	65,66 €	65,66 €
Socket head cap screw	ISO4762	M5x10	4	0,03 €	0,04 €	0,16 €
Socket head cap screw	ISO4762	M5x12	4	0,03 €	0,04 €	0,15 €
Torque nut	ISO7040	M5	2	0,02 €	0,02 €	0,04 €
			Total standard parts		**67,27 €**	

7.3.1.5 Frame

Designed components

Table 44: Price calculation of the designed components of the frame.

Description	QTY	Material cost/unit (net)	Machining cost/unit (net)	+indirect cost (20%)	+ profit yield (25%)	+taxes (23%)=(total/unit)	Total
Frame_right	1	93,56 €	90,00 €	108,00 €	135,00 €	281,12 €	281,12 €
Frame_left	1	93,56 €	90,00 €	108,00 €	135,00 €	281,12 €	281,12 €
Top_plate_frame	2	3,94 €	9,00 €	10,80 €	13,50 €	21,45 €	42,90 €
Bottom_plate_frame	2	3,94 €	7,50 €	9,00 €	11,25 €	18,68 €	37,37 €
Front_plate_frame	2	2,94 €	9,00 €	10,80 €	13,50 €	20,22 €	40,44 €
Mounting_start_button	1	10,38 €	10,50 €	12,60 €	15,75 €	32,14 €	32,14 €
Connection_plate_steel_structure_babyplast	2	1,00 €	14,75 €	17,70 €	22,13 €	28,44 €	56,89 €
Connection_plate_start _and_babyplast	2	0,77 €	23,75 €	28,50 €	35,63 €	44,77 €	89,53 €

Description	QTY	Material cost/unit (net)	Machining cost/unit (net)	+indirect cost (20%)	+ profit yield (25%)	+taxes (23%)=(total/unit)	Total
L-profile-40x40x2x1005	4	1,41 €	5,50 €	6,60 €	8,25 €	11,88 €	47,53 €
L-profile-40x40x2x305	4	0,40 €	5,50 €	6,60 €	8,25 €	10,64 €	42,56 €
Welding_plate_for_feet	8	0,27 €	17,00 €	20,40 €	25,50 €	31,70 €	253,58 €
				Total designed components		1205,17 €	

Standard components

Table 45: Price calculation of the standard components of the frame.

Description	Standard	Length	QTY	Price/unit	+23% taxes=(total/unit)	Total
Hex screw grade c	ISO4018	M12X60	24	0,12 €	0,15 €	3,51 €
Hex screw grade c	ISO4018	M12x30	24	0,08 €	0,09 €	2,21 €
Torque nut	ISO7040	M12	48	0,07 €	0,09 €	4,31 €
4901/4/C			8	13,48 €	16,58 €	132,64 €
				Total standard parts	142,68 €	

7.3.1.6 Jigs

Designed components

Table 46: Price calculation of the designed components of the jigs.

Description	QTY	Material cost/unit (net)	Machining cost/unit (net)	+indirect cost (20%)	+ profit yield (25%)	+taxes (23%)=(total/unit)	Total
First_injection_top_gabarrit	1	2,05 €	43,75 €	52,50 €	65,63 €	83,24 €	83,24 €
Second_injection_bottom_gabarrit	1	6,37 €	41,50 €	49,80 €	62,25 €	84,40 €	84,40 €

Description	QTY	Material cost/unit (net)	Machining cost/unit (net)	+indirect cost (20%)	+ profit yield (25%)	+taxes (23%)=(total/unit)	Total
Middle_support_holder _gabarrit_down	5	2,05 €	41,50 €	49,80 €	62,25 €	79,09 €	395,45 €
Middle_support_holder _gabarrit_up	4	2,05 €	45,25 €	54,30 €	67,88 €	86,01 €	344,03 €
Cylinder_gabarrit	4	2,32 €	2,00 €	2,40 €	3,00 €	6,54 €	26,17 €
Second_injection_top_gabarrit	1	2,32 €	167,50 €	201,00 €	251,25 €	311,89 €	311,89 €
				Total designed components		1245,18 €	

Standard components

Table 47: Price calculation of the standard components of the frame.

Description	Standard	Length	QTY	Price/unit	+taxes (23%)	Total Price
Socket head cap screw	ISO4762	M6x35	12	0,04 €	0,04 €	0,54 €
Magnets			24	3,00 €	3,69 €	88,56 €
				Total standard parts		89,10 €

7.3.1.7 Safety design

The cost of the complete safety design is €4459,33. This price includes all the materials such as the frame, the safety screen, etc. (Annex 7.1.1)

7.3.2 Cost to assemble the manipulator

The total cost to assemble the manipulator on one injection machine is estimated to be around 1152,00 € (Table 48).

Table 48: Estimated assembly cost

	Days	Hours/ day	Cost/hour	Total Cost
Assembly cost	8	8/day	18 €/hour	1152,00 €

7.3.3 Cost for welding

The total cost to weld the frame to one injection machine is estimated to be around 432,00 € (Table 49).

Table 49: Estimated welding cost

	Days	Hours/ day	Cost/hour	Total Cost
Welding cost	3	8/day	18 €/hour	432,00 €

7.3.4 Total cost of the project

Table 50: Summary of the total material cost of the project.

	quantity	Total cost/unit	Total cost for 2 injection machines
gripper system	4	2364,41 €	9457,64 €
lever system	4	2209,14 €	8836,54 €
connection gripper+lever+energy chain	4	75,71 €	302,84 €
frame	2	1347,85 €	2695,71 €
jigs	2	1334,28 €	2668,57 €
safety equipment	2	4459,33 €	8918,66 €
		Total	**32 879,95 €**

Table 51: Summary of the total assembly cost of the project.

	days	hours/day	Cost/hour	Total cost
Cost for the assembly	16	8	18,00 €	2304,00 €
cost for welding	6	8	18,00 €	864,00 €
			Total	**3168,00 €**

So the total cost for the manpipulator system for two injection machines is 36 047,95 € (32 879,95 € + 3 168,00 €).

7.3.5 Cost estimation of material based on weight

Table 52: Factors considered for the price calculation of the material.

	AW6082	S235	PTFE
density[kg/mm³]	2,70E-06	7,80E-06	2,20E-06
price(€) per kg (sheet)	4,6	1,1	6,5
price(€) per kg (rod)	5	1,4	6,5

Table 53: Price calculation of the parts.

Gripping strutcture	L	W	T	Volume(mm³) /unit	Material	cost/ unit
Longer sides	25	620	30	465000	AW6082	5,78 €
Short sides	45	220	30	297000	AW6082	3,69 €
Gripper_parallel holder	20	130	30	78000	AW6082	0,97 €
Lock_up_parallel holder	55	20	30	33000	AW6082	0,41 €
Lock_down_parallel_holder	15	20	30	9000	AW6082	0,11 €
Middle support holder	20	240	30	144000	AW6082	1,79 €
Side_bridge_holders	90	150	20	270000	AW6082	3,35 €
span_bridge	30	236	30	212400	AW6082	2,64 €
plate_bridge	165	226	5	186450	AW6082	2,32 €
Fixed distance plate	117,5	152	15	267900	AW6082	3,33 €
L-guidance	50	55	40	110000	AW6082	1,37 €
Lock_gripper	136	40	30	163200	PTFE	2,33 €
Cilinder_mounting	60	45	12,5	33750	AW6082	0,42 €
Lever system	**L**	**W**	**T**	**Volume(mm³) /unit**	**Material**	**cost/ unit**
Lowest_mounting_plate_vertical_cylinder	127,5	175	12	267750	AW6082	3,33 €
Highest_mounting_plate_vertical_cylinder	135	175	12	283500	AW6082	3,52 €
Aluminium_guiding_rod				65940	AW6082	0,89 €
Lever_arm	320	170	15	816000	AW6082	10,13 €
Lever_Arm_holding_block	185	140	12	310800	AW6082	3,86 €
St_fastening_block_lever_arm_holder	150	255	21	803250	S235	6,89 €
Alu_block1	150	132	27	534600	AW6082	6,64 €
Alu_block2	150	50	27	202500	AW6082	2,52 €

Lever system	L	W	T	Volume(mm³) /unit	Material	cost/ unit
Guide_block_for_linear_guide	30	22	12	7920	AW6082	0,10 €
Rod_for_block_linear_guide				1884	AW6082	0,03 €
bearing housing	80	45	45	162000	AW6082	2,01 €
Mounting Block Linear Guide	**L**	**W**	**T**	**Volume(mm³) /unit**	**Material**	**cost/ unit**
Horizontal	726	36	20	522720	AW6082	6,49 €
Vertical	26	105	20	54600	AW6082	0,68 €
Backplate	680	100	10	680000	AW6082	8,45 €
Mounting Bracket Caterpillar	**L**	**W**	**T**	**Volume(mm³) /unit**	**Material**	**cost/ unit**
L-bracket	160	28	2	8960	AW6082	0,11 €
Frame support	**L**	**W**	**T**	**Volume(mm³) /unit**	**Material**	**Cost /unit**
top	900	255	2	459000	S235	3,94 €
front	900	190	2	342000	S235	2,93 €
bottom	900	255	2	459000	S235	3,94 €
welding_plate_for_feet	40	40	20	32000	S235	0,27 €
L_40x40x2				32108	AW6082	0,40 €
L_40x40x2				113308	AW6082	1,41 €
Connection_plate_steel_structure_babyplast	260	45	10	117000	S235	1,00 €
Connection_plate_start_and_babyplast	200	45	10	90000	S235	0,77 €
Gabarrits	**L**	**W**	**T**	**Volume(mm³) /unit**	**Material**	**cost/ unit**
2nd gabarrit						
Guiding cylinders (DIAM22,5)x470				186780,9375	AW6082	2,52 €
Support_halves	33	250	20	165000	AW6082	2,05 €
end of conduit support halves	33	250	62,2	513150	AW6082	6,37 €
1st gabarrit						
Guiding cylinders (DIAM22,5)x470				186780,9375	AW6082	2,52 €
Support halves	33	250	20	165000	AW6082	2,05 €

Gabarrits	**L**	**W**	**T**	**Volume(mm³) /unit**	**Material**	**cost/ unit**
end of conduits support halves	33	250	20	165000	AW6082	2,05 €
Acessoires to fasten the BabyPlast	**L**	**W**	**T**	**Volume(mm³) /unit**	**Material**	**cost/ unit**
for start stop	200	45	10	90000	S235	0,77 €
for the steel structure	260	45	10	117000	S235	1,00 €
scrap gripper	**L**	**W**	**T**	**Volume(mm³) /unit**	**Material**	**cost/ unit**
Height adjusting				14616,7	AW6082	0,20 €
Gripper	18,5	29	12	6438	AW6082	0,08 €
Extension_on_cylinder				3629,84	AW6082	0,05 €
Bottom_scrap_gripper	36	36	22,5	29160	AW6082	0,36 €
Top_scrap_gripper	40	40	20	32000	AW6082	0,40 €

7.3.6 Cost estimation machining process

Quantity	Part name	CNC Milling time	€/h	Cost 1	Turning time	€/h	Cost 2	Drilling/Threading time	€/h	Cost 3	Finishing time	€/h	Cost 4	Cutting time	€/h	Cost 5	COST/PART	TOTAL
2	Mounting plate gripper	0	45	0	0	32	0	0,3	25	7,5	0,15	20	3	0	30	0	10,50 €	21,00 €
4	Lever system	0,25	45	11,25	0	32	0	0,35	25	8,75	0,2	20	4	0	30	0	24,00 €	96,00 €
4	Fixed distance plate gripper	0,35	45	15,75	0	32	0	0,45	25	11,25	0,3	20	6	0	30	0	33,00 €	132,00 €
4	Middle holder scrap gripper	0,25	45	11,25	0	32	0	0,2	25	5	0,15	20	3	0	30	0	19,25 €	77,00 €
4	Side holder scrap gripper	0,25	45	11,25	0	32	0	0,2	25	5	0,15	20	3	0	30	0	19,25 €	77,00 €
4	Lock down gripper	0,25	45	11,25	0	32	0	0,15	25	3,75	0,1	20	2	0	30	0	17,00 €	68,00 €
4	Locking gripper	0,4	45	18	0	32	0	0,15	25	3,75	0,2	20	4	0	30	0	25,75 €	103,00 €
4	Lock up gripper	0,3	45	13,5	0	32	0	0,25	25	6,25	0,2	20	4	0	30	0	23,75 €	95,00 €
2	Longer side 1	0,5	45	22,5	0	32	0	0,4	25	10	0,3	20	6	0	30	0	38,50 €	77,00 €
2	Longer side 2	0,5	45	22,5	0	32	0	0,4	25	10	0,3	20	6	0	30	0	38,50 €	77,00 €
8	L guidance lock gripper	0,3	45	13,5	0	32	0	0,2	25	5	0,15	20	3	0	30	0	21,50 €	172,00 €
4	Middle support holder for gripper	0,25	45	11,25	0	32	0	0,15	25	3,75	0,15	20	3	0	30	0	18,00 €	72,00 €
2	Short side gripping system	0,2	45	9	0	32	0	0,2	25	5	0,1	20	2	0	30	0	16,00 €	32,00 €
2	Vertical side 1 gripping system	0,35	45	15,75	0	32	0	0,15	25	3,75	0,2	20	4	0	30	0	23,50 €	47,00 €
2	Vertical side 2 gripping system	0,35	45	15,75	0	32	0	0,15	25	3,75	0,2	20	4	0	30	0	23,50 €	47,00 €
2	Vertical side 3 gripping system	0,35	45	15,75	0	32	0	0,15	25	3,75	0,2	20	4	0	30	0	23,50 €	47,00 €
2	Vertical side 4 gripping system	0,35	45	15,75	0	32	0	0,15	25	3,75	0,2	20	4	0	30	0	23,50 €	47,00 €

Quantity	Part name	CNC Milling time	€/h	Cost 1	Turning time	€/h	Cost 2	Drilling/Threading time	€/h	Cost 3	Finishing time	€/h	Cost 4	Laser Cutting time	€/h	Cost 5	COST/PART	TOTAL
2	Bottom plate frame	0	45	0	0	32	0	0	25	0	0	20	0	0,25	30	7,5	7,50 €	15,00 €
2	Connection plate steel	0,2	45	9	0	32	0	0,15	25	3,75	0,1	20	2	0	30	0	14,75 €	29,50 €
2	Front plate frame	0	45	0	0	32	0	0	25	0	0	20	0	0,3	30	9	9,00 €	18,00 €
2	Connection plate start	0,2	45	9	0	32	0	0,15	25	3,75	0,1	20	2	0,3	30	9	23,75 €	47,50 €
2	Top plate frame	0	45	0	0	32	0	0	25	0	0	20	0	0,3	30	9	9,00 €	18,00 €
8	Welding plate for feet	0,25	45	11,25	0	32	0	0,15	25	3,75	0,1	20	2	0	30	0	17,00 €	136,00 €
4	Span long sides gripper	0,15	45	6,75	0	32	0	0,2	25	5	0,1	20	2	0	30	0	13,75 €	55,00 €
4	Cylinder mounting block lock gripper	0,35	45	15,75	0	32	0	0,3	25	7,5	0,2	20	4	0	30	0	27,25 €	109,00 €
4	Vertical support holder guidance rail	0,3	45	13,5	0	32	0	0,3	25	7,5	0,2	20	4	0	30	0	25,00 €	100,00 €
10	Rod for block linear guide	0	45	0	0,25	32	8	0	25	0	0,1	20	2	0	30	0	10,00 €	100,00 €
4	Guiding block for linear guide	0,4	45	18	0	32	0	0,15	25	3,75	0,15	20	3	0	30	0	24,75 €	99,00 €
2	Fixing plate lever arm	0,4	45	18	0	32	0	0,15	25	3,75	0,15	20	3	0	30	0	24,75 €	49,50 €
2	Guide and mounting plate lever system highest	1,2	45	54	0	32	0	0,35	25	8,75	0,3	20	6	0	30	0	68,75 €	137,50 €
2	Guide and mounting plate lever system lowest	0,4	45	18	0	32	0	0,3	25	7,5	0,15	20	3	0	30	0	28,50 €	57,00 €
6	Guiding cylinder	0	45	0	0,25	32	8	0	25	0	0	20	0	0	30	0	8,00 €	48,00 €
2	Backplate mounting linear guide	0,25	45	11,25	0	32	0	0,25	25	6,25	0,1	20	2	0	30	0	19,50 €	39,00 €
4	Holder guiding rail cylinder	0,3	45	13,5	0	32	0	0,8	25	20	0,25	20	5	0	30	0	38,50 €	154,00 €
2	Al block lever holder	0,4	45	18	0	32	0	0,3	25	7,5	0,15	20	3	0	30	0	28,50 €	57,00 €
2	Al Bblock 2 lever arm	0,35	45	15,75	0	32	0	0,3	25	7,5	0,15	20	3	0	30	0	26,25 €	52,50 €
2	St block holder lever arm	0,5	45	22,5	0	32	0	0,4	25	10	0,3	20	6	0	30	0	38,50 €	77,00 €
4	Lever arm	1	45	45	0	32	0	0,5	25	12,5	0,4	20	8	0	30	0	65,50 €	262,00 €
34	Bearing housing	0,5	45	22,5	0	32	0	0,4	25	10	0,1	20	2	0	30	0	34,50 €	1.173,00 €
4	Bottom scrap gripper	0,8	45	36	0	32	0	0,4	25	10	0,2	20	4	0	30	0	50,00 €	200,00 €
4	Extension on cylinder	0	45	0	0,35	32	0	0,15	25	3,75	0,1	20	2	0	30	0	5,75 €	23,00 €
8	Gripper	0,9	45	40,5	0	32	0	0,15	25	3,75	0,25	20	5	0	30	0	49,25 €	394,00 €
4	Height adjusting	0,15	45	6,75	0,35	32	0	0	25	0	0,15	20	3	0,2	30	6	15,75 €	63,00 €
4	Top scrap gripper	1	45	45	0	32	0	0	25	0	0,2	20	4	0	30	0	49,00 €	196,00 €
4	Cylinder gabarit	0	45	0	0	32	0	0	25	0	0,1	20	2	0	30	0	2,00 €	8,00 €
4	Middle support holder gabarot up	0,75	45	33,75	0	32	0	0,3	25	7,5	0,2	20	4	0	30	0	45,25 €	181,00 €
1	Second injection bottom gabarit	0,75	45	33,75	0	32	0	0,15	25	3,75	0,2	20	4	0	30	0	41,50 €	41,50 €
5	Middle support holder gabarit down	0,75	45	33,75	0	32	0	0,15	25	3,75	0,2	20	4	0	30	0	41,50 €	207,50 €
1	Second injection top gabarit (EDM)	3,5	45	157,5	0	32	0	0	25	0	0,5	20	10	0	30	0	167,50 €	167,50 €
1	First injection top gabarit	0,8	45	36	0	32	0	0,15	25	3,75	0,2	20	4	0	30	0	43,75 €	43,75 €

Quantity	Part name	CNC Milling time	€/h	Cost 1	Turning time	€/h	Cost 2	Drilling/Threading time	€/h	Cost 3	Finishing time	€/h	Cost 4	Laser Cutting time	€/h	Cost 5	COST/PART	TOTAL
1	frame right	0	45	0	0	32	0	0	25	0	0	20	0	3	30	90	90,00 €	90,00 €
1	frame left	0	45	0	0	32	0	0	25	0	0	20	0	3	30	90	90,00 €	90,00 €
1	L-bracket energy chain	0	45	0	0	32	0	0	25	0	0	20	0	0,15	30	4,5	4,50 €	4,50 €
1	Mounting_start_button	0	45	0	0	32	0	0	25	0	0	20	0	0,35	30	10,5	10,50 €	10,50 €
1	L-profile-40x40x2x1005	0	45	0	0	32	0	0,1	25	2,5	0	20	0	0,1	30	3	5,50 €	5,50 €
1	L-profile-40x40x2x305	0	45	0	0	32	0	0,1	25	2,5	0	20	0	0,1	30	3	5,50 €	5,50 €

7.4 Fiser vs BabyPlast

A comparison between some crucial factors that can save money during the operation and lifetime of the machine have been set out in Table 54, Table 55, Table 56 and Table 57.

Table 54: Cost analyse Set-Up Fiser vs BabyPlast.

Cost analyse-Set-Up	
Fisher Machine Set-Up	**Values**
Set up (35 min/setup)	12 h/day = 2880 h/year
Cost/year	28 800 € / machine= 2800€
Baby plast set-up	**Values**
Set up (12 min)	4 h/day = 960 h/ year
Cost / year	9600 €
Savings/year	**19 200,00 €**

Table 55:Cost analyse-Raw material waste in set-up and start of production Fiser vs BabyPlast.

Cost analyse-Raw material waste in set-up and start of production	
Fiser Machine – Raw material waste in set-up and start of production	**Values**
Raw material waste	2 Kg/day = 480 Kg/year
Cost/year	960 €
Babyplast - Raw material waste in set-up and start of production	**Values**
Raw material waste	128 g/day = 30,72 Kg/year
Cost / year	61,40 €
Savings/year	**898,60 €**

Table 56: Costs analysis-Raw material consumption saving Fiser vs BabyPlast.

Costs analyses-Raw material consumption saving	
Fiser molds – sprue weight per number of cavity	**Costs/year**
Jeep Cabo- impact of gate per part- 0,84g	5192 €
Baby molds - sprue weight per number of cavity	**Costs/year**
Jeep Cabo-impact of gate per part- 0,25g	1273 €
Savings/year	**3919 €**

Table 57: Cost analysis-Maintenance saving Fiser vs BabyPlast.

Cost analysis- Maintenance saving	
Fiser Machine Maintenance	
Reparations	3248 €
Materials maintenance	925 €
Preventive maintenance	885 €
Tools maintenance	1945 €
Total	7003 €
Expected cost in BabyPlast	
Reparations	400 €
Materials maintenance	150 €
Preventive maintenance	200 €
Tools maintenance	300 €
Total	1050 €
Savings/year	**5953 €**

7.5 Nesting

In the manufacturing industry, *nesting* refers to the process of laying out cutting patterns to minimize raw material waste. By putting cutting lines together, a decrease in cutting time can also be accomplished if a plasma cutter is used. After designing all the components, the ones with the same thickness and material, are put into a *nesting* program. The outcome of the *nesting* software provides an idea of how much of a standardized plate we need. In this alinea, all the designed parts are put in the *nesting* software on a standardized sheet/plate to see how much of the plate we will exactly be needing.

Aluminium

Aluminium 5 mm Thickness

The parts that are nested can be seen in Table 58 and the outcome of the nesting program can be seen in Figure 116.

Table 58: Parts nested in AW6082-5mm.

Description	QTY	Material	Dimensions [mm]	Supplier
Mounting_plate_gripper	4	AW6082	165 x 226 x5	PolyLanema

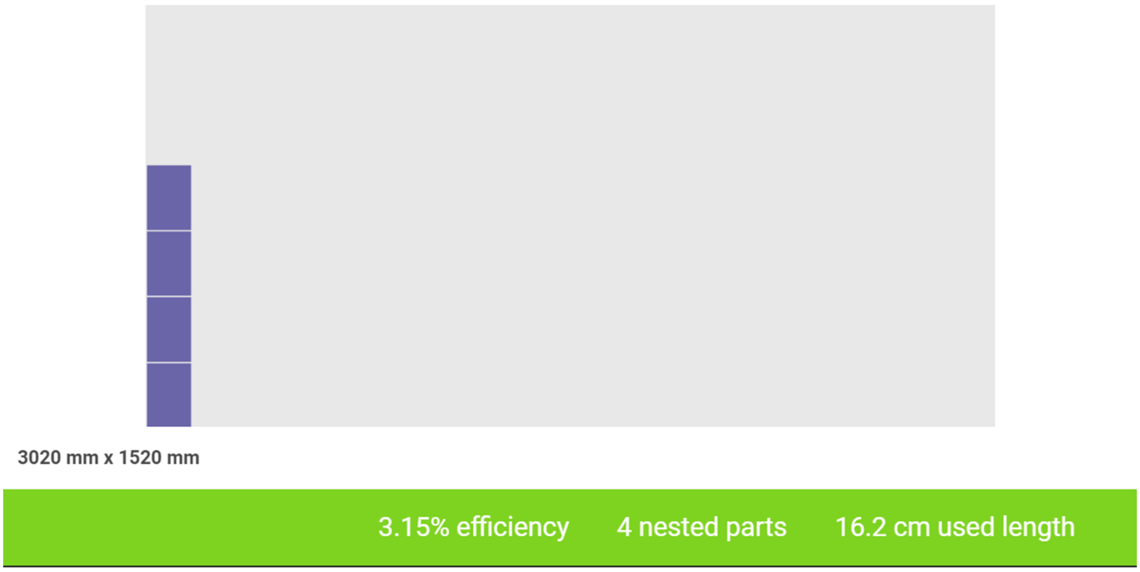


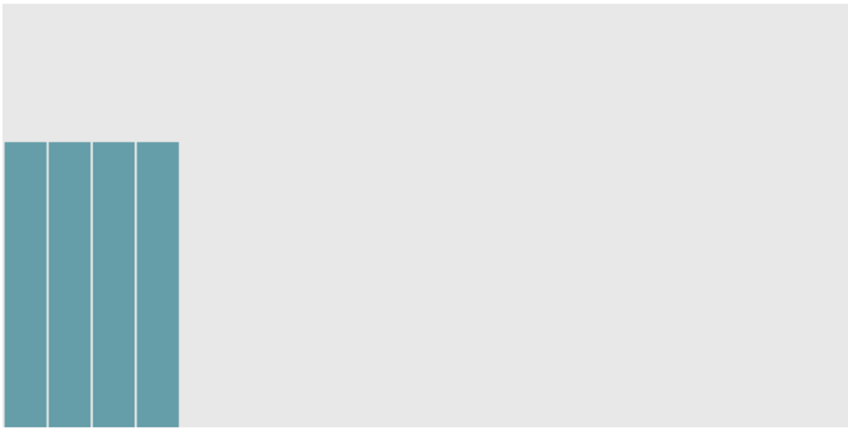
Figure 116: Outcome of the nesting software for AW6082-5mm.

Aluminium 10 mm Thickness

The parts that are nested can be seen in Table 59and the outcome of the nesting program can be seen in Figure 117.

Table 59: Parts nested in AW6082-10mm.

Description	QTY	Material	Dimensions [mm]	Supplier
Backplate_mounting_linear_guide	2	AW6082	680 x 100 x 10	Poly Lanema



2020 mm x 1020 mm

13.2% efficiency 4 nested parts 42 cm used length

Figure 117: Outcome of the nesting software for AW6082-10mm.

Aluminium 12 mm Thickness

The

Description	QTY	Material	Dimension	Supplier
Fixed_distance_plate	8	AW6082	117,5 x 152 x 15	Poly Lanema
Lever_arm	8	AW6082	320 x 170 x 15	Poly Lanema

parts that are nested can be seen in Table 60and the outcome of the nesting program can be seen in Figure 118.

Table 60: Parts nested in AW6082-12mm.

Description	QTY	Material	Dimensions [mm]	Supplier
Lowest mounting plate vertical cylinder	4	AW6082	127,5 x 175 x 12	Poly Lanema
Highest mounting plate vertical cylinder	4	AW6082	135 x 175 x 12	Poly Lanema
Fixing_plate_lever_arm	4	AW6082	185 x 40 x 12	
Guiding_block_for_linear_guide	8		30 x 22 x 12	
Gripper	16		18,5 x 29 x 12	
Cylinder_mounting_block_lock_gripper	8		60 x 45 x 12	

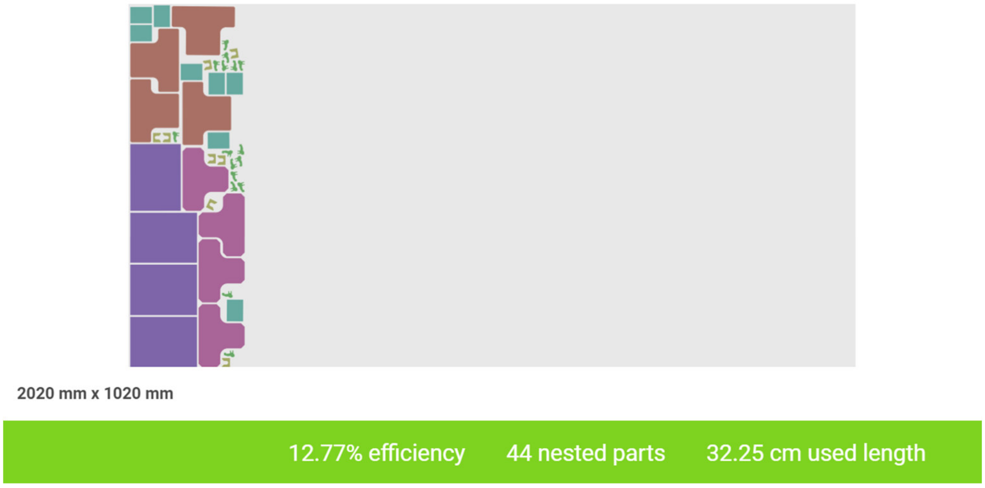


Figure 118 : Outcome of the nesting software for AW6082-12mm.

Aluminium 15 mm Thickness

The parts that are nested can be seen in
Table 61and the outcome of the nesting program can be seen in Figure 119.

Table 61: Parts nested in AW6082-15mm.

Description	QTY	Material	Dimension	Supplier
Fixed_distance_plate	8	AW6082	117,5 x 152 x 15	Poly Lanema
Lever_arm	8	AW6082	320 x 170 x 15	Poly Lanema

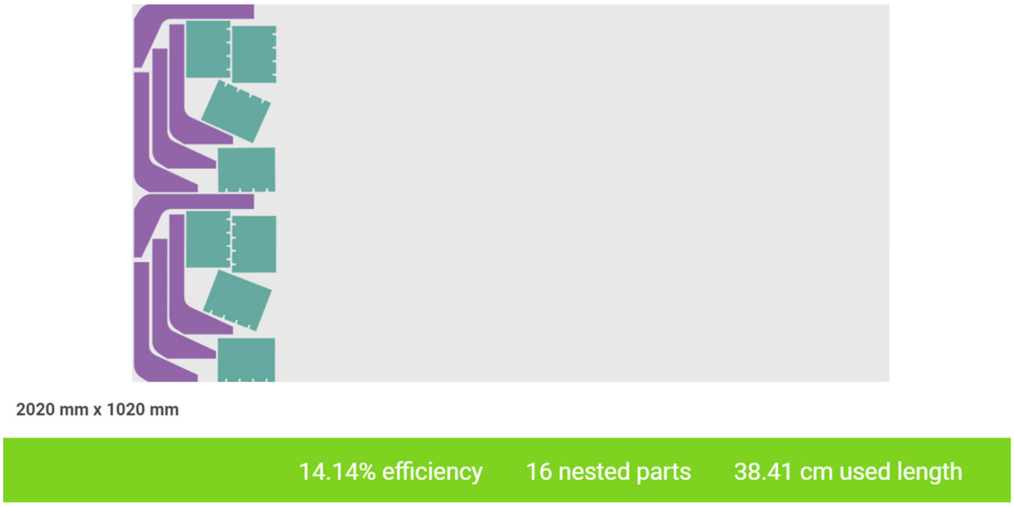


Figure 119: Outcome of the nesting software for AW6082-15mm.

Aluminium 20 mm Thickness

The parts that are nested can be seen in Table 62 and the outcome of the nesting program can be seen in Figure 120.

Table 62: Parts nested in AW6082-20mm.

Description	QTY	Material	Dimensions [mm]	Supplier
Vertical_sides	16	AW6082	90 x 150 x 20	
Holder_guiding_rail_cylinder	8		726 x 36 x 20	
Vertical_support_holder_guiding_rail	8		26 x 105 x 20	
Support_holders_jig_top	4		33 x 250 x 20	
Support_holder_jig_bottom	5		33 x 250 x 20	
First injection_end_of_jig	1		33 x 250 x 20	
Top_scrap_gripper	8		40 x 40 x 20	

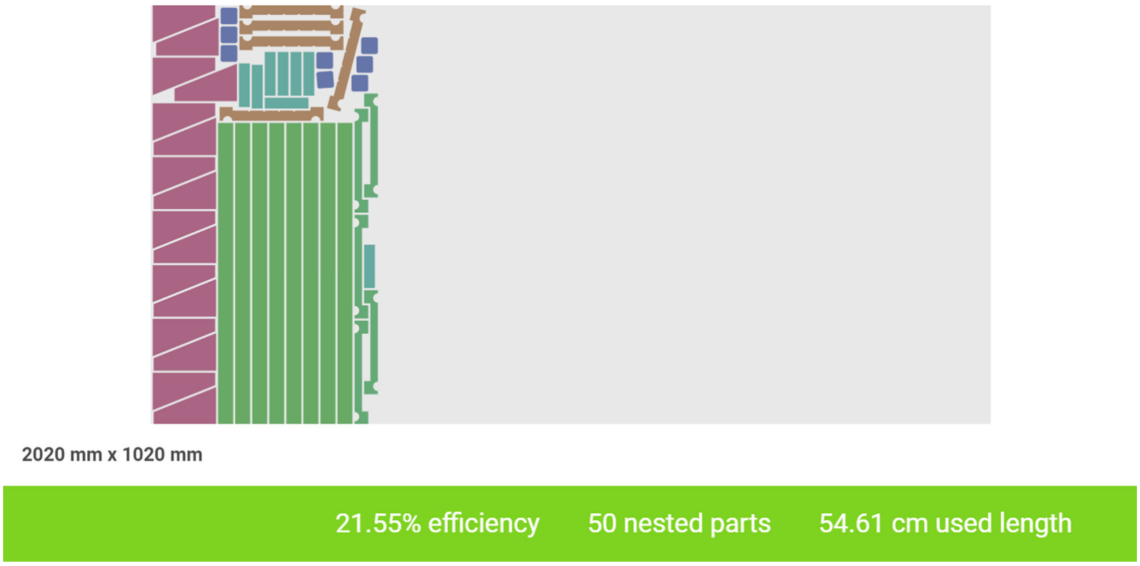


Figure 120: Outcome of the nesting software for AW6082-20mm.

Aluminium 30 mm Thickness

The parts that are nested can be seen in Table 63 and the outcome of the nesting program can be seen in Figure 121.

Table 63: Parts nested in AW6082-30mm.

Description	QTY	Material	Dimensions [mm]	Supplier
Longer_sides	8		25 x 620 x 30	
Short_sides	12		45 x 220 x 30	
Middle_holder_scrap_gripper	8		20 x 130 x 30	
Lock_up_parallel holder	8		55 x 20 x 30	
Lock_down_parallel_holder	8		15 x 20 x 30	
Middle_support_holder_for_gripper	8		20 x 240 x 30	
Span_bridge	8		30 x 236 x 30	
Alu-block1	4		150 x 132 x 27	
Alu-block2	4		150 x 50 x 27	

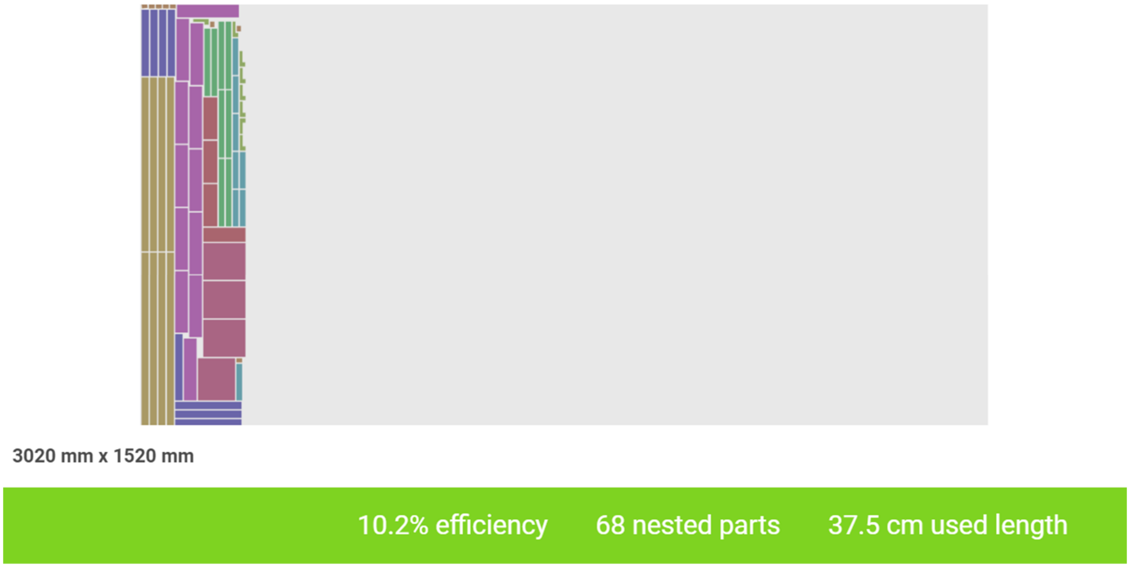


Figure 121: Outcome of the nesting software for AW6082-30mm.

Aluminium 35 mm Thickness

The parts that are nested can be seen in Table 64 and the outcome of the nesting program can be seen in Figure 122.

Table 64: Parts nested in AW6082-35mm.

Description	QTY	Material	Dimensions [mm]	Supplier
2nd injection gabarrit top and bottom	2	AW6082	20 x 250 x 33	

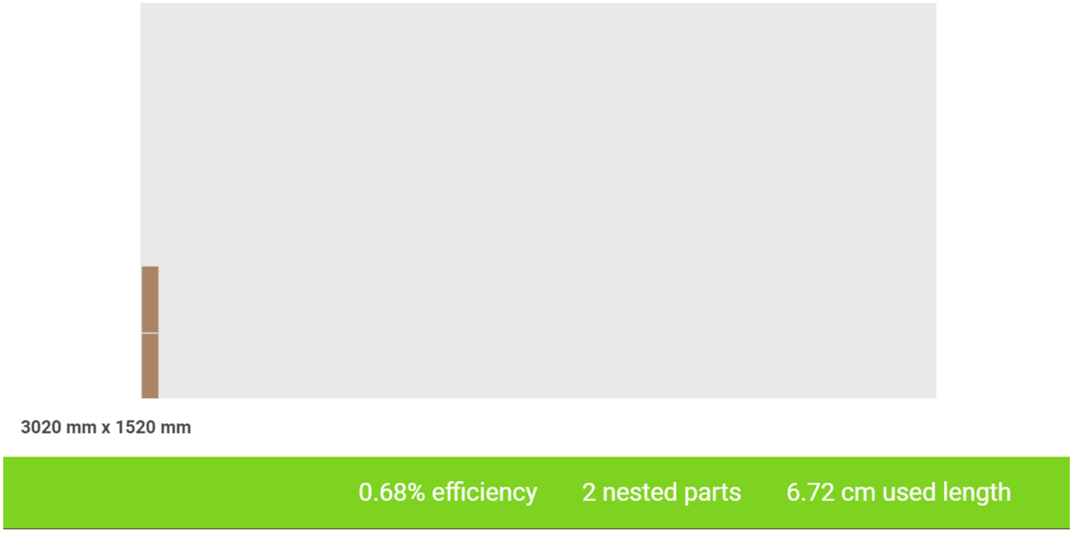


Figure 122: Outcome of the nesting software for AW6082-35mm.

Aluminium 45 mm Thickness

The parts that are nested can be seen in Table 65 and the outcome of the nesting program can be seen in Figure 123.

Table 65: Parts nested in AW6082-45mm.

Description	QTY	Material	Dimensions [mm]	Supplier
Bearing_housing	12	AW6082	80 x 45 x 45	

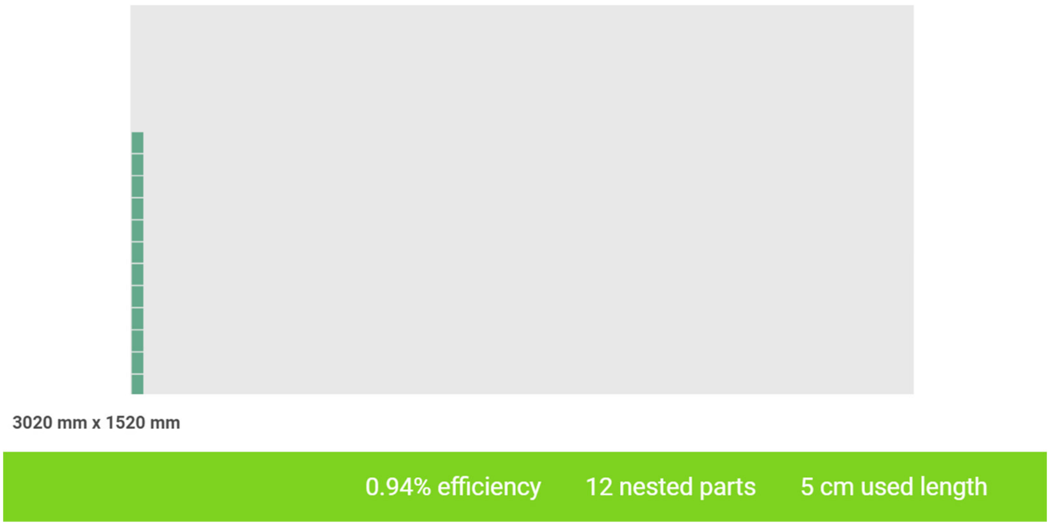


Figure 123: Outcome of the nesting software for AW6082-45mm.

Aluminium 55 mm Thickness

The parts that are nested can be seen in Table 66 and the outcome of the nesting program can be seen in Figure 124.

Table 66:Parts nested in AW6082-55mm.

Description	QTY	Material	Dimensions [mm]	Supplier
L-guidance_locking gripper	8	AW6082	65 x 40 x 55	

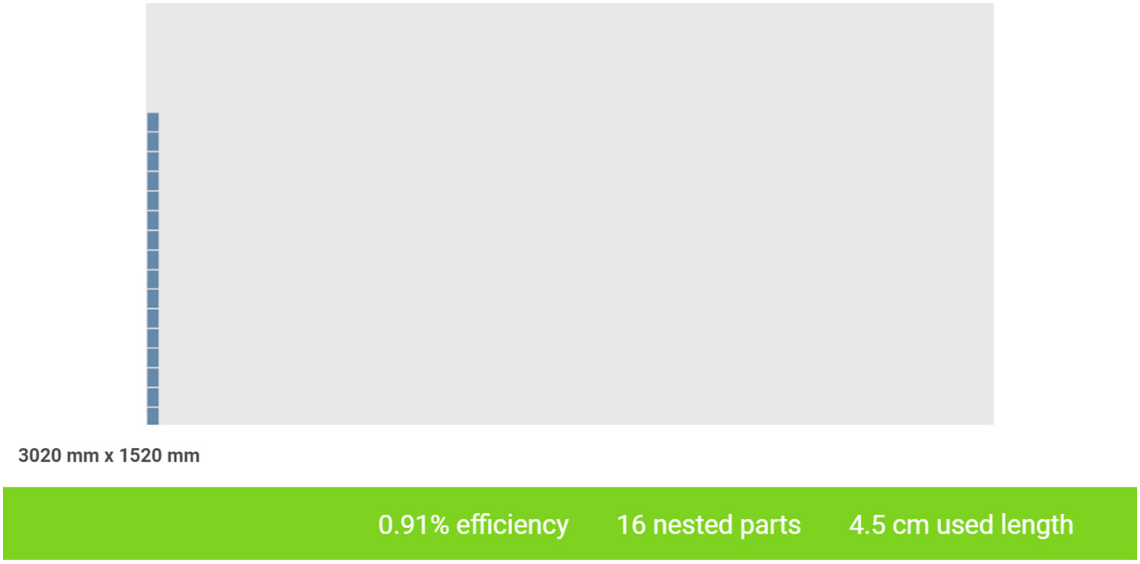


Figure 124:Outcome of the nesting software for AW6082-55mm.

PTFE

Thickness 30 mm

The parts that are nested can be seen in Table 67 and the outcome of the nesting program can be seen in Figure 125.

Table 67: Parts nested in PTFE-30mm.

Description	QTY	Material	Dimensions [mm]	Supplier
Locking_gripper	8	AW6082	65 x 40 x 55	

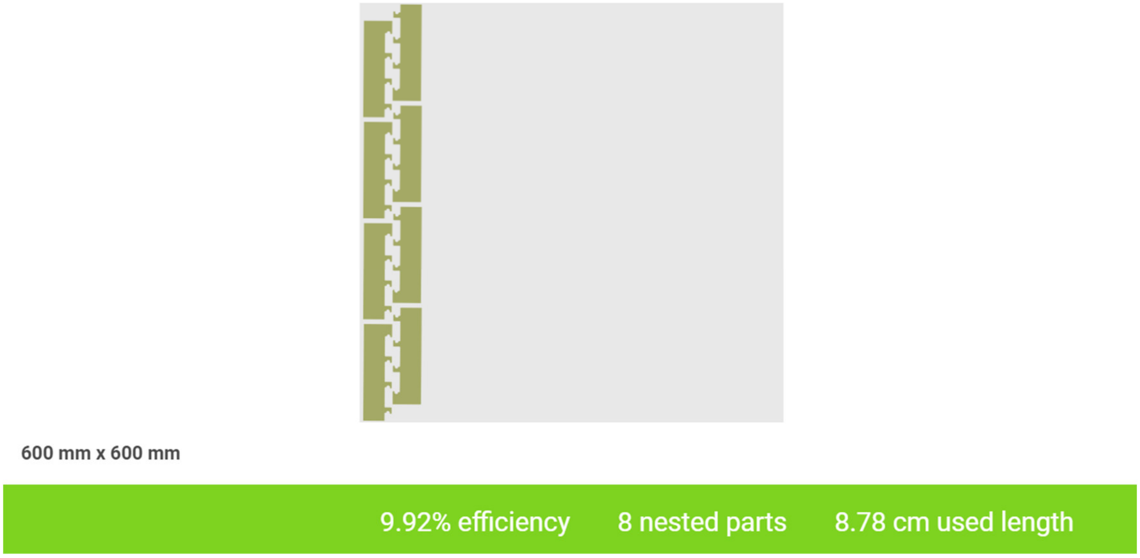


Figure 125: Outcome of the nesting software for PTFE-30mm.

Steel

Steel 5 mm Thickness

The parts that are nested can be seen in Table 68 and the outcome of the nesting program can be seen in Figure 126.

Table 68: Parts nested in S235JR-5mm.

Description	QTY	Material	Dimensions [mm]	Supplier
Steel frame plating: top	4	S235	255 x 900 x 5	
Steel frame plating: bottom	4	S235	255 x 900 x 5	
Steel frame plating: front	4	S235	190 x 900 x 5	

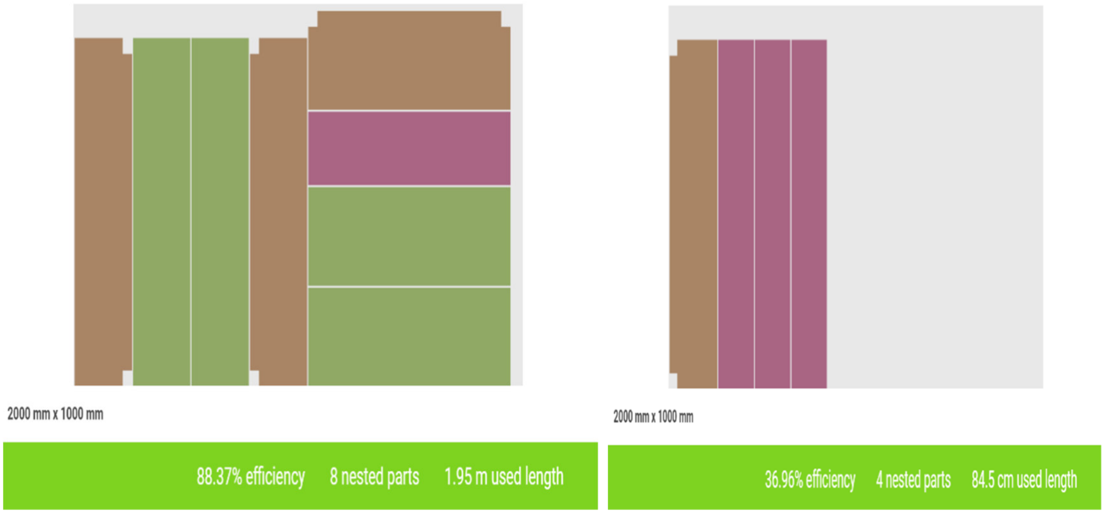


Figure 126: Outcome of the nesting software for S235JR-5mm.

Steel 10 mm thickness

The parts that are nested can be seen in Table 69 and the outcome of the nesting program can be seen in Figure 127.

Table 69: Parts nested in S235JR-10mm.

Description	QTY	Material	Dimensions [mm]	Supplier
Fastening plate for start/stop to the BabyPlast	4	S235	45 x 200 x 10	
Fastening plate for the steel structure to the BabyPlast	4	S235	45 x 260 x 10	

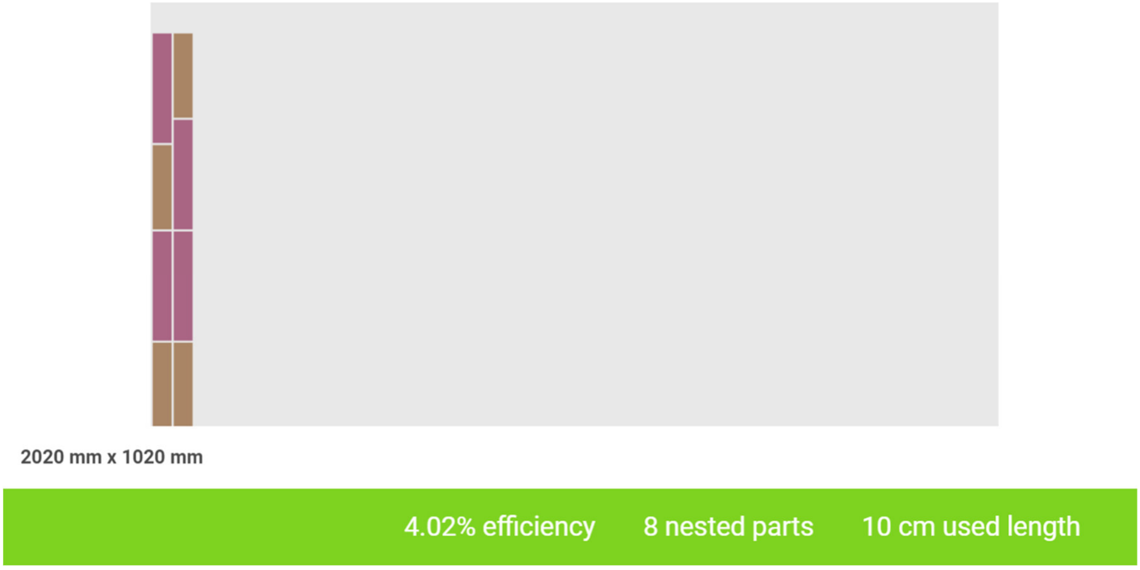


Figure 127: Outcome of the nesting software for S235JR-10mm.

Steel 20 mm thickness

The parts that are nested can be seen in Table 70 and the outcome of the nesting program can be seen in Figure 128.

Table 70:Parts nested in S235JR-20mm.

Description	QTY	Material	Dimensions [mm]	Supplier
Welding_plate_for_feet	20	S235	40 x 40 x 20	

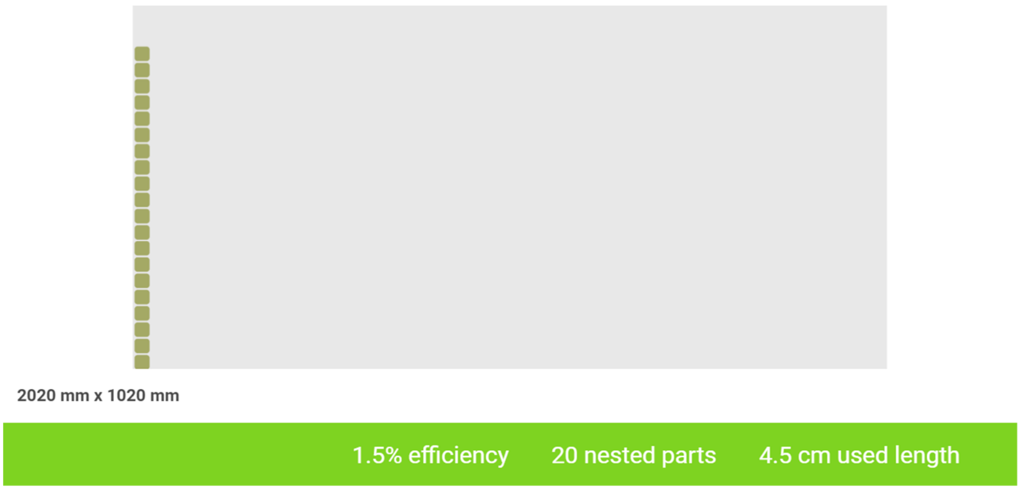


Figure 128:Outcome of the nesting software for S235JR-20mm.

Steel 25 mm thickness

The parts that are nested can be seen in Table 71 and the outcome of the nesting program can be seen in Figure 129.

Table 71: Parts nested in S235JR-25mm.

Description	QTY	Material	Dimensions [mm]	Supplier
St_block_holder_lever _arm	4	S235	150 x 255 x 21	

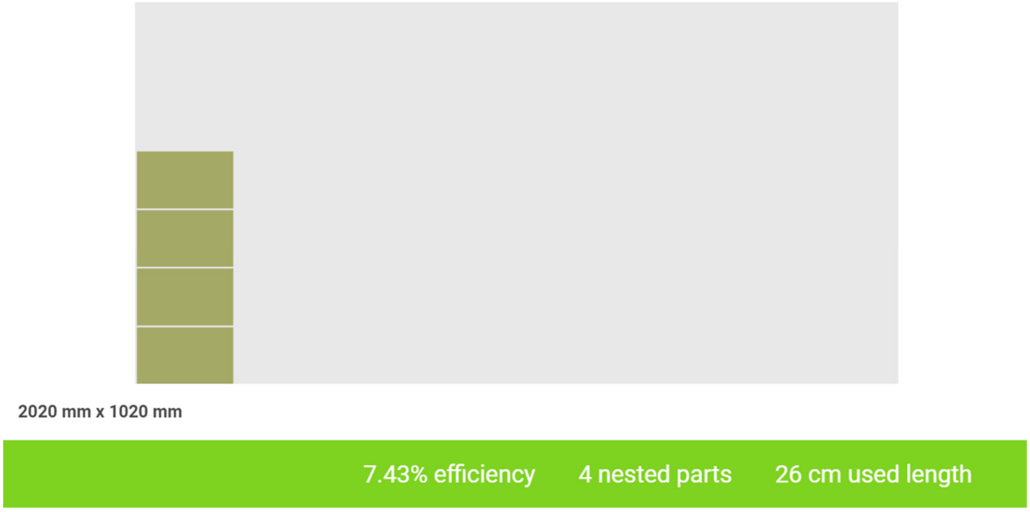


Figure 129: Outcome of the nesting software for S235JR-25mm.

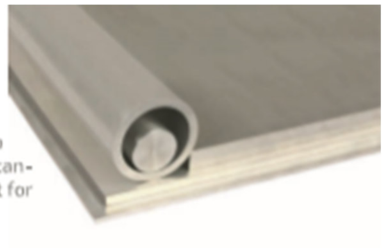
7.6 Materials

7.6.1 AW6082

SERIES 6000

AW 6082 (Al Si1MgMn)

6082 aluminium is a medium mechanical resistance and high resistance to corrosion alloy. In the 6000 series, it is the alloy that presents better resistance being able to replace 6021 alloy in many applications. It is also excellent for welding.



CHEMICAL COMPOSITION (WEIGHT %) (EN 573 - 3)

ELEMENTS	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Minimum	0.7	-	-	0.4	0.6	-	-	-	-
Maximum	1.3	0.5	0.1	1	1.2	0.25	0.2	0.1	Rest

MECHANICAL PROPERTIES

PLATES (EN 485-2)

THICKNESS (mm)	TEMPER	Rm* (MPa)	Rp0.2* (MPa)	A50 (%)	A (%)	HB - BRINELL HARDNESS
1.5 - 3	T6	310	260	7	7	94
3 - 6		310	260	10	10	94
6 - 12.5	T651	300	255	9	9	91
12.5 - 60		295	240	-	8	89
60 - 100		295	240	-	7	89
100 - 150		275	240	-	6	84
150 - 175		275	230	-	4	83

*Minimum values

ROUND RODS (EN 755-2) - EXTRUDED

DIAMETER (mm)	Rm* (MPa)	Rp0.2* (MPa)	A (%)	A50 (%)	HB - BRINELL HARDNESS
< 20	295	250	8	6	95
20 - ≤ 150	310	260	8	-	95
150 - ≤ 200	280	240	6	-	95
200 - < 250	270	200	6	-	95

ROUND RODS (EN 754-2) - CALIBRATED

DIAMETER (mm)	Rm* (MPa)	Rp0.2* (MPa)	A (%)	A50 (%)	HB - BRINELL HARDNESS
≤ 80	310	255	10	9	95

*Minimum values

MAIN CHARACTERISTICS

- Good weldability
- Good resistance to corrosion
- Good polishing
- Good anodizing

APPLICATIONS

- Railway rails
- Shipbuilding industry
- Jigs and accessories
- Tools
- Footwear moulds

SERIES 6000

PHYSICAL PROPERTIES

DENSITY	2.70 g/cm³
MODULUS OF ELASTICITY	70 000 MPa
LINEAR EXPANSION COEFFICIENT	23.4 x 10⁻⁶/K
THERMAL CONDUCTIVITY	170 W/mK
ELECTRICAL CONDUCTIVITY	27 m/Ohm mm²

DELIVERY PROGRAM

SHEETS

THICKNESSES (mm)	DIMENSIONS (mm)	SHEET WEIGHT(kg)	STOCK T651
2	1000 x 2000	11.13	●
3	1520 x 3020	37.20	●
4	1520 x 3020	49.60	●
5	1520 x 3020	61.97	●

Average weights of production / Other dimensions available on request.

PLATES

THICKNESSES (mm)	DIMENSIONS (mm)	PLATE WEIGHT(kg)	STOCK T651
6	1520 x 3020	74.37	●
8	1000 x 2000	44.51	●
	1270 x 2520	69.13	●
	1520 x 3020	99.15	●
10	1020 x 2020	55.65	●
	1270 x 2520	86.41	●
	1520 x 3020	123.94	●
12	1020 x 2020	66.76	●
	1270 x 2520	103.69	●
	1520 x 3020	148.73	●
15	1020 x 2020	83.45	●
	1270 x 2520	129.62	●
	1520 x 3020	185.91	●
20	1020 x 2020	111.26	●
	1270 x 2520	172.82	●
	1520 x 3020	247.88	●
25	1020 x 2020	139.08	●
	1270 x 2520	216.03	●
	1520 x 3020	309.85	●
30	1520 x 3020	371.82	●
35	1520 x 3020	433.79	●
40	1270 x 2520	345.64	●
40	1520 x 3020	495.76	●
45	1520 x 3020	557.73	●
50	1270 x 2520	432.05	●
50	1520 x 3020	619.70	●
55	1520 x 3020	681.67	●
60	1270 x 2520	518.47	●
60	1520 x 3020	743.65	●
65	1520 x 3020	805.62	●
70	1270 x 2520	604.88	●
70	1520 x 3020	867.59	●
75	1520 x 3020	929.56	●
80	1520 x 3020	991.53	●
90	1520 x 3020	1115.47	●
100	1520 x 3020	1239.41	●
120	1520 x 3020	1487.29	●
150	1520 x 3020	1859.20	●

Average weights of production / Other dimensions available on request.

● Standard: generally available from stock. ◐ Semi-standard: generally not available from stock.
○ Non-standard: generally not available from stock, manufactured to order and subject to special conditions.

ROUND RODS

DIAM.(mm) EXTRUDED	WEIGHT (kg/m)	STOCK T6	STOCK T651
Standard lenght 3000mm			
20	0.879	●	·
22	1.064	●	·
25	1.374	●	·
30	1.979	●	·
35	2.693	●	●
40	3.518	●	·
45	4.552	●	●
50	5.497	●	●
55	6.652	●	·
60	7.916	●	●
65	9.291	●	·
70	10.775	●	·
75	12.370	●	·
80	14.074	●	·
85	15.888	●	●
90	17.813	●	·
95	19.837	◐	·
100	21.991	●	·
110	26.609	●	·
120	31.667	●	●
130	37.165	●	·
140	43.102	●	·
150	49.480	●	·
160	56.297	●	·
170	63.554	●	·
180	71.251	●	·
190	77.900	◐	·
200	86.300	●	·
203	90.800	●	·
210	95.200	●	·
250	135.000	◐	·
260	146.000	◐	·
300	194.300	◐	·

Average weights of production.
Other diameters available on request.

ROUND RODS

DIAM.(mm) CALIBRATED h9/h11	PESO (kg/m)	STOCK T6
Standard lenght 3000mm		
8	0.140	●
9	0.187	●
10	0.219	●
12	0.316	●
14	0.431	●
15	0.494	●
16	0.562	●
18	0.712	●
20	0.879	●
22	1.064	●
25	1.374	●
26	1.486	●
28	1.724	●
30	1.979	●
31	2.113	●
32	2.251	●
35	2.693	●
36	2.850	●
38	3.175	●
40	3.518	●
41	3.696	○
42	3.879	○
43	4.066	○
45	4.552	◐
48	5.066	○
50	5.497	◐
55	6.652	◐
60	7.916	◐

Average weights of production.
Other diameters available on request.

BARRAS QUADRADADAS

THICK.(mm) EXTRUDED	WEIGHT (kg/m)	STOCK T6
Standard lenght 3000mm		
30	2.520	●
32	2.867	●
35	3.340	●
40	4.480	●
45	5.670	●
50	7.000	●
60	10.080	●

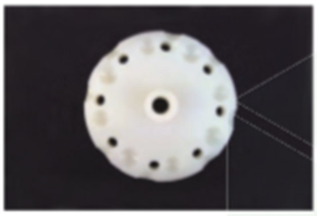
Average weights of production.
Other thicknesses available on request.

7.6.2 PTFE

GENERAL USE PLASTICS

PTFE

PTFE stands out for its flame resistance: it is classified as a "non-combustible" material in the air according to ASTM D365 test method. This material has low resistance to gamma radiation: for example, an exposure to 70 Megarads reduces the tensile strength by 50%. It has good mechanical properties, even at very low temperatures and excellent fatigue resistance, especially in applications involving bending or vibration.



MAIN CHARACTERISTICS

- Wide range of temperatures -200°C to +260°C
- Almost total resistance to all chemicals
- Very low coefficient of friction
- Non-flammable
- Excellent dielectric properties
- Good mechanical properties
- Excellent resistance to fatigue
- Total resistance to ageing, moisture and ultraviolet rays
- Non-toxic

APPLICATIONS

- Permeability
- Friction
- Electrical insulation
- Anti-corrosion
- General mechanics

GENERAL USE PLASTICS

TECHNICAL DATASHEET

PROPERTIES	UNITS	VIRGIN PTFE
DENSITY	g/cm^3	2.13-2.19
THERMAL PROPERTIES		
THERMCAL CONDUCTIVITY	cal/s/cm/ºC	$5 - 11 \times 10^{-4}$
COEFF. OF LINEAR THERMAL EXPANSION (23ºC - 260ºC)	ºC	$10-15 \times 10^{-5}$
MECHANICAL PROPERTIES		
TENSILE STRENGTH	MPa	25 - 30
RUPTURE DEFORMATION	%	250 - 400
SHORE HARDNESS	SHORE D	55 - 60
DYNAMIC FRICTION COEFFICIENT	-	0.06 - 0.15
FLUENCY	%	-
PRESSURE/VELOCITY FACTOR - P.V. (3.5m/min)	$kg/cm^2 \times m/s$	-
ELECTRICAL PROPERTIES		
VOLUME RESISTIVITY	Ohm x cm	$>10^{18}$
SURFACE RESISTIVITY	Ohm	$>10^{17}$

GENERAL USE PLASTICS

DELIVERY PROGRAM

SHEETS

THICKNESS (mm)	TOLERANCES		600 x 600	1000 x 1000	1200 x 1200	1500 x 1500	2000 x 1000
1	+0.10	0	◕	◕	●	◕	◕
1.5	+0.20	0	◕	◕	●	◕	◕
2			◕	◕	●	◕	◕
2.5	+0.30	0	◕	◕	●	◕	◕
3			◕	◕	●	◕	◕
4	+0.35	0	◕	◕	●	◕	◕
4.5	+1.00	0	◕	◕	◕	◕	◕
5			◕	◕	●	◕	◕
6	+1.20	0	◕	◕	●	◕	◕

PLATES

THICKNESS (mm)	TOLERANCES		600 x 600	1000 x 1000	1200 x 1200	1500 x 1500	2000 x 1000
8	+1.20	0	◕	◕	●	◕	◕
10	+1.50	0	◕	◕	●	◕	◕
12			◕	◕	●	◕	◕
15			◕	◕	●	◕	◕
20			◕	◕	●	◕	◕
25			◕	◕	●	◕	◕
30			◕	◕	●	◕	◕
35			◕	◕	●	-	-
40			◕	◕	●	-	◕
45			◕	◕	◕	-	-
50			◕	◕	●	-	◕
60	+15%	0	◕	◕	●	-	-
70			◕	◕	◕	-	-
80			◕	◕	◕	-	-
90			◕	-	◕	-	-
100			◕	-	◕	-	-
110			◕	-	-	-	-
120			◕	-	-	-	-
130			◕	-	-	-	-
140			◕	-	-	-	-
150			◕	-	-	-	-

ROUND RODS

DIAMETERS (mm)	TOLERANCES		PTFE
Standard length 1000 mm			
4	0	+0.3	◕
5			◕
6			●
7			◕
8	0	+0.4	●
9			◕
10			●
11			◕
12			●
13			◕
14			◕
15	0	+0.8	●
16			●
17			◕
18			●
19			◕
20			●
22			◕
25	0	+1.2	●
28			●
30			●
32			◕
35	0	+1.6	●
38			◕
40			●
42			◕
45	0	+2.0	●
50			●
55	0	+2.4	●
60			●
65	0	+2.8	●
70			●
75	0	+3.2	●
80			●
85	0	+3.6	●
90			●
100	0	+4.0	●
110			●
120			●
130	0	+5.0	●
140			●
150			●
160			●
170	0	+6.0	●
180			●
200			●
Other standard lengths: 2000 mm (de 4-120 mm thickness) 3000 mm (de 4-120 mm thickness)			

7.6.3 s235

S235JR All

General Information

Soft structural steel easy to weld and bend.

Variants suitability for hot dip zinc coating according the classification in Table 1 EN 10025-2:2004: Class 1: Si max 0,030% and Si + 2,5 P max 0,090%. Class 2: Si max 0,035%. Class 3 Si 0,14...0,25% and P max 0,035%.

Similar designations

SS 1312, S235JR, 1.0038, Fe 360 BFN, RSt37-2, 40 B

Chemical composition

Variant	Cast	Weldability		C %	Mn %	P %	S %	Cu %	N %
S235JR EN10025-2 (ref)	Std	CEV 0.35$_{max}$	Min	-	-	-	-	-	-
		Pcm 0.25$_{max}$	Max	0.17	1.40	0.035	0.035	0.55	0.0120

S235JR: C max 0,20 % for sizes over 40 mm. Only CEV required in standard

SS 1312: Not binding recommendation for Mn (0,4 - 0,7) % in standard

Mechanical Properties

Variant	Condition	Format	Dimension [mm]	Yield strength min [MPa]	Tensile strength [MPa]	Elongation A_5 [%]	Impact (ISO-V) strength$_{min}$
S235JR EN10025-2 (ref)	+AR	All formats	< 16	235*	360-510	26	20 °C 27 J (long)
		All formats	16.1 < 40	225*	360-510	26	20 °C 27 J (long)
		All formats	40.1 < 63	215*	360-510	25	20 °C 27 J (long)
		All formats	63.1 < 100	215*	360-510	24	20 °C 27 J (long)
		All formats	100.1 < 150	195*	350-500	22	20 °C 27 J (long)
		All formats	150.1 < 200	185*	340-490	21	20 °C 27 J (long)

$Rp_{0.2}$ * R_{eh}, ** R_{el}

Transformation temperatures

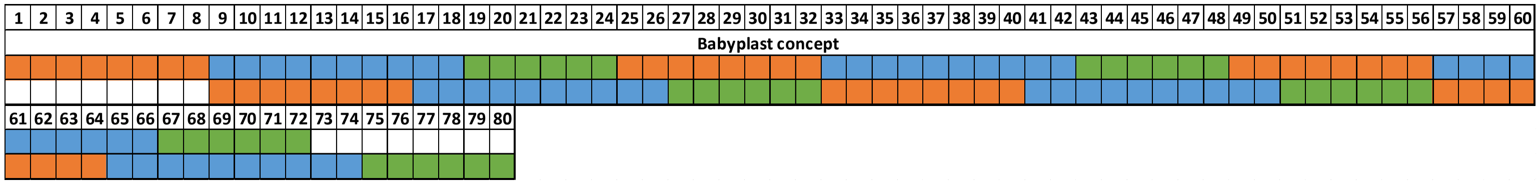
	Temperature °C
MS	485
AC1	725
AC3	863

Other properties (typical values)

Youngs module (GPa)	Poisson´s ratio (-)	Shear module (GPa)	Density (kg/m3)
210	0.3	80	7800
Average CTE 20-300°C (µm/m°K)	**Specific heat capacity 50/100°C (J/kg°K)**	**Thermal conductivity Ambient temperature (W/m°K)**	**Electrical resistivity Ambient temperature (µΩm)**
12	460 - 480	40 - 45	0.20 - 0.25

7.7 Cycle time overview of the designed concept

CYLINDER MOVEMENTS TIMING							
Description					vpiston[m/s]		
locking	CDQSB20-5DM	0,2	0,031	0,055	0,690065559	0,005	0,01
scrap grip	CDQSB20-5D	0,015	0,021	0,055	1,748014747	0,005	0,00
HORIZONTAL	MY1B25-500				0,2	0,5	2,50
VERTICAL	ADN-40-50-APA						0,10
INJECTION TIME							
10							
PUTTING IN CONDUITS							
10							
OPERATING CYCLE							
put in conduits	8,00						
injection	10,00	put in conduits	8,00				
down	0,10	injection	10,00				
lock	0,01	down	0,10				
up	0,10	lock	0,01				
sideways	2,50	up	0,10				
eject	0,01	sideways	2,50				
sideways	2,50	eject	0,01				
Total	23,21	sideways	2,50				
		TOTAL	23,21				
Manipulator time	5,21						



	Babyplast(x2)
complete cycles in one min	4,67
complete cycles in one hour	280,02
#over injected parts	1120,08

7.8 2D Drawings